

NSR-23-005-527
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REMOTE SENSING IN MICHIGAN FOR LAND RESOURCE MANAGEMENT: Highway Impact Assessment

Report No. 190800-1-T, December 1972

 **ENVIRONMENTAL
RESEARCH INSTITUTE
OF MICHIGAN**
Ann Arbor, Michigan



**MICHIGAN STATE UNIVERSITY
East Lansing, Michigan**

**In Cooperation with
Michigan Department of State Highways**

**Prepared for
Office of University Affairs
National Aeronautics and Space Administration
Washington, D. C.**

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Infrared and Optics Division
Environmental Research Institute of Michigan

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FOREWORD

This project was performed for the Office of University Affairs, National Aeronautics and Space Administration by the Environmental Research Institute of Michigan (ERIM), with joint participation by faculty and research staff members of Michigan State University (MSU) acting in the role of subcontractor. The Environmental Research Institute of Michigan is a non-profit corporation established on January 1, 1973 as a successor to the Willow Run Laboratories of The University of Michigan. The Institute's number for this report is 190800-1-T.

The goal of this project is to develop and apply earth resource survey technology to problems in land resource management. The project undertook the acquisition and analysis of data over selected test areas in Southeast Michigan to demonstrate the use of remote sensing in the solution of current problems involving land use planning, such as site selection and development or environmental monitoring. A more general goal of the project is to improve presently available methods of land evaluation as a contribution to the increasingly important government functions of land use planning and policy formulation.

This is one of several reports presenting the results of this project. The work is continuing under separate grants to the Environmental Research Institute and to Michigan State University with joint effort being devoted to additional tasks on land resource management problems of current interest in the State of Michigan.

The investigations described herein were performed under NASA Contract NSR 23-005-527 with Joseph A. Vitale, Chief, Engineering Design Branch, Office of University Affairs, acting as Technical Monitor. The Project Director for this work was Richard R. Legault, Associate Director of ERIM, and the Principal Investigator was Irvin J. Sattinger, Research Engineer at ERIM. The portion of the technical program conducted by Michigan State University was performed under the direction of Myles G. Boylan, Director of the School of Urban Planning and Landscape Architecture, and Dr. Raymond D. Vlasin, Chairman of the Department of Resource Development.

Contributions to this investigation were also made by other members of the research staff of ERIM and faculty and staff of MSU.

At ERIM, Thomas W. Wagner, Research Associate, was responsible for remote sensing analysis and interpretation of soils, hydrology, and vegetation, with special emphasis on the application of the multispectral scanner imagery. He was aided by Tim W. D. Gregg, Assistant in Research. A. N. Sellman, Research Associate, was responsible for ERIM activity on remote

sensing analysis of land use. Other staff members contributing to the effort include Fabian C. Polcyn, Research Engineer and Head, Technology Applications Group; Philip G. Hasell, Research Engineer, aircraft facility supervision; Leo A. Levereault, Research Associate, aircraft flight coordination; and Roland D. Kistler, Associate Research Engineer, multispectral scanner data processing.

Major contributions to this investigation at MSU were made by the following faculty and staff. Dr. Eugene P. Whiteside, Professor in the Department of Crop and Soil Sciences, Dr. Wayne Myers, Assistant Professor in the Department of Forestry, and Dr. Delbert Mokma, Research Associate in the Department of Crop and Soil Sciences were responsible for the investigations of soil and vegetation impacts. Dr. James Ahl, Research Associate, Stephen Schar, Research Specialist, and Mark Sullivan were responsible for the land use investigations. William Buckler and Mary Daup supervised and completed the cartographic tasks. The photographic interpretation and ground truth collection necessary to the research was carried out by William Enslin, George Cincala, Stanley Gorlitsky, and Kenneth Ottman under the supervision of John Fischer. Valuable assistance in data analysis and report writing was provided by Bryan Ernst, Linda Greenberg, Patricia Hagedon, Charlene Higgins and Mark Wilson.

This study was performed in cooperation with the Environmental Liaison Unit of the Transportation Planning Division, Michigan Department of State Highways. The Unit, which is charged with carrying out evaluations of the impact of highway projects throughout the State of Michigan, provided guidance by defining its responsibilities and current practices, recommending an appropriate test site, and reviewing the investigation results. The investigation results reported herein do not, however, necessarily reflect the views of the Department.

Acknowledgment is due for the assistance given the project by G. Robert Adams, Supervisor, Environmental Liaison Unit, and Jan H. Raad, Environmental Specialist in the Unit.

ABSTRACT

An existing section of M-14 freeway constructed in 1964 and a projected extension from Ann Arbor to Plymouth, Michigan provides an opportunity for an investigation of the potential uses of remote sensing techniques in providing objective information needed for assessing the impact of highway construction. Remote sensing data included multispectral scanner imagery and aerial photography.

Only minor effects on vegetation, soils, and land use were found to have occurred in the existing corridor. Adverse changes expected to take place in the corridor proposed for extension of the freeway can be minimized by proper design of drainage ditches and attention to good construction practices.

Remote sensing can be used to collect and present many types of data useful for highway impact assessment on land use, vegetation categories and species, soil properties and hydrologic characteristics.

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REMOTE SENSING IN MICHIGAN FOR LAND RESOURCE MANAGEMENT: Highway Impact Assessment

1 SUMMARY

An investigation was conducted of the potential uses of remote sensing techniques for providing objective information needed for assessing the impact of highway construction. A test site northeast of Ann Arbor, Michigan was selected for study which includes a section of existing M-14 freeway constructed in 1964 and a projected extension of this freeway to Plymouth, Michigan. Remote sensing data included multispectral scanner imagery taken from altitudes of 600 m and 2100 m, RB-57 photography taken from 20,000 m, and other aerial photography. The Michigan Department of State Highways and local government agencies also cooperated in supplying much useful information. Other sources of information included soil surveys, topographic maps, soil and water samples, and ground measurements of surface temperatures, and spectral characteristics.

It was found that only minor effects on vegetation, soils, and land use occurred in the existing corridor. In the corridor for the proposed extension of the freeway, some adverse changes in plant communities and water levels will probably occur. These effects can be minimized by proper design of drainage ditches and attention to good construction practices. It is anticipated that the presence of the completed highway link will lead to the conversion of agricultural and forested land at new interchanges to residential, commercial or industrial developments.

The investigation indicated that remote sensing methods can be used to collect and present certain types of data useful for highway impact assessment on land use, vegetation categories and species, soil properties, and hydrologic characteristics. Interpretation of aerial photography was used to identify and map vegetation in four major categories (forest, brushland and mixed cover, herbaceous perennials, and annuals or bare areas). It was also used to study land use changes occurring over the nine-year period since the existing freeway section was built. Soil surveys provide information on soil texture, natural drainage, and surface slope.

The demonstration of multispectral scanner methods concentrated on those techniques which have been most fully developed. Scanner methods can be used to map surface water distribution. Various classes of natural drainage of the soil can be distinguished where bare soil can be observed, but results derived from remote sensing interpretation should be carefully field checked. General categories of vegetation can be mapped, as well as individual species. A number of additional methods of scanner analysis are under development in connection with other projects and should eventually be considered for adoption.

For ease in analysis and presentation, maps of soils, vegetation, topography, surface water, and land use can be prepared in the form of a base map and a set of transparent overlays. This method of presentation allows the character and spatial relationship of these various surface features to be displayed and compared.

Recommendations are made for further evaluation of remote sensing techniques as a basis for adopting the most effective techniques for highway impact assessment.

2
INTRODUCTION

2.1. NEED FOR IMPACT ASSESSMENT METHODS

The nation's extensive highway building program has been of great benefit to the general public, providing increased mobility at low cost for both personal and business purposes while giving consideration to handling traffic volume and increasing highway safety. At the same time, each new highway has many potential secondary effects, both favorable and unfavorable, which need to be carefully considered if the primary benefits are not to be seriously diluted.

In order to ensure the protection of the environment, recent federal legislation has been passed, including the National Environmental Policy Act of 1969 and the Federal Aid Highway Act of 1970. This legislation requires the preparation and submission of environmental impact statements by state highway commissions prior to the construction of new highways.

At the present time, there are no clearly established methods for either carrying out a highway impact study or reporting the results, but substantial attention is being devoted to developing such methods. The fully developed methods must be based on a set of accepted criteria for evaluating ecological, social, and economic impacts of highway construction. The kinds of relevant and useful information needed for making the assessment must be determined, and suitable procedures adopted for using the information to predict and estimate impact in accordance with the basic criteria. Current impact assessment methods and possible approaches for improving them are discussed in Section 4.

2.2. GOALS OF REMOTE SENSING INVESTIGATION

This report describes an investigation of the potential uses of remote sensing techniques for providing some of the objective information needed for assessing the social, economic, and ecological impacts of highway construction. Although the data pertain to a specific case, the results can be evaluated for more general application.

A test site northeast of Ann Arbor, Michigan was selected which includes a section of existing M-14 freeway and a projected right-of-way for extension of this freeway to Plymouth, Michigan. Existing and new remote sensor data and other natural resource data were assembled, and extensive ground investigation was carried out in the study area to support and evaluate the data analysis. A number of potential economic, social and ecological impacts of the highway construction and maintenance were examined.

This study was undertaken after the final selection of the highway right-of-way had been made. Consequently, the evaluation of the probable impact of highway construction was confined largely to the selected route. In practice, impact assessment should be undertaken at a much earlier stage in the route location process, at which time the conclusions reached can be given an appropriate weight in the overall selection process.

In Section 5, a rather broad description is given of the most critical construction effects, but further consideration is then restricted to those effects amenable to remote sensing analysis. The assessment of these effects through remote sensing analysis should eventually be incorporated into a complete method of highway impact assessment which considers all pertinent aspects of the impact and their integration into a valid meaningful assessment on which actions can be soundly based.

2.3. IMPACT ASSESSMENT AT THE M-14 TEST SITE

Computer-processed multispectral scanner data and aerial photography, ground truth collection, and generally available published data sources were used to provide up-to-date vegetation, soil factor, surface water system, and land use information for the study area. This information was used both to determine changes which had occurred in the vicinity of the existing section of M-14 freeway since its construction and to predict changes which can be expected to occur in the area of new construction. Investigation procedures are fully described in Section 6.

The analysis and interpretation of multispectral scanner and aerial camera data were conducted by three teams, one for soils and hydrology, one for vegetation, and one for land use. The Environmental Research Institute of Michigan (ERIM) and Michigan State University (MSU) were represented on each team. Scanner data acquired by ERIM's NASA-supported C-47 aircraft were processed and interpreted by the ERIM staff to map surface water distribution, soil characteristics, and vegetation in the area as one basic source of information for the impact assessment process (Section 8). Available aerial photography was also extensively used for detailed analysis of land use and natural features in the area. The MSU staff analyzed aerial photography taken at various times since before the freeway section was built.

The results of the data acquisition and interpretation tasks were presented in several forms. As described in Section 6, a series of transparent overlays were prepared by MSU for each of three segments of the study area (see Fig. 1). Segment I contains the existing M-14 corridor, and Segments II and III contain the western and eastern portions, respectively, of the proposed M-14 corridor extension in Washtenaw County. These overlays provided a set of base maps and separately recorded information at the same scale on soil texture, drainage, and slope, four categories of vegetation (forest, brushland or mixed, herbaceous perennials, and bare soil or annuals), and land use. Multispectral scanner data were processed and analyzed

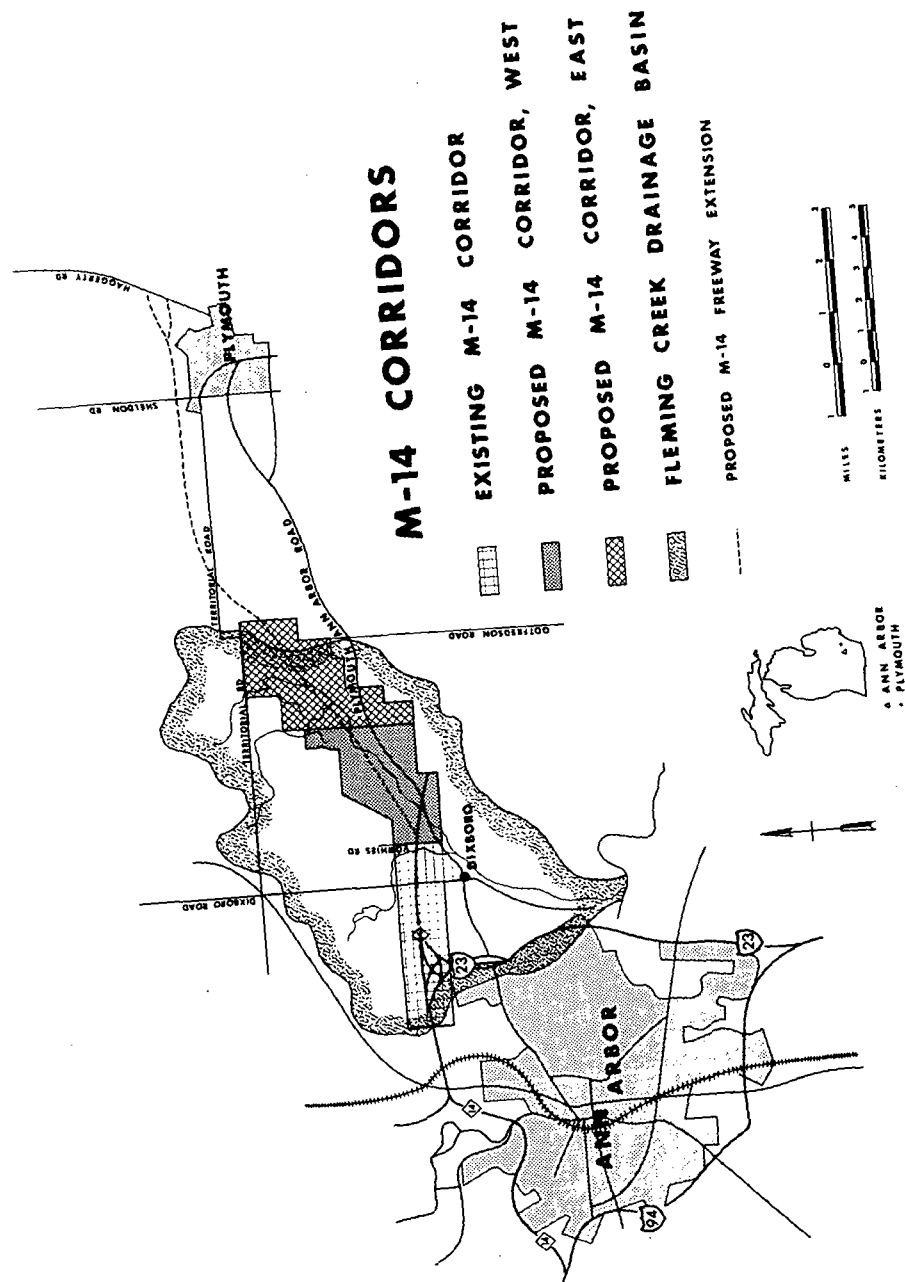


FIGURE 1. LOCATION OF M-14 TEST SITE

by ERIM for portions of the area to produce separate recognition maps of vegetation types, soil drainage properties, and surface water (Section 8).

Past changes in the vicinity of the existing M-14 highway (Segment I) were assessed on the basis of these data, and anticipated changes in the area of new construction (Segments II III) were predicted. The changes in soils and the surface water system since the construction of the existing section of M-14 appear to be very slight. Five borrow pits and gravel pits have resulted from the construction work. Study of the proposed construction area suggests the consideration of such measures as use of sediment basins for runoff waters, the use of mulching and seeding or sodding exposed soil, and design of drainage ditches to maintain proper water table levels. A change in the highway route at one point could decrease the environmental impact by avoiding a large area of poorly drained mineral soils and organic soils.

The study of vegetation indicates little change in the vegetation communities in Segment I. The one exception occurs at the interchange with U.S. Highway 23 where high water has remained in a wet woodland long enough to cause some mortality of trees. There has been a general trend throughout the area of previously cultivated land reverting to grass and brush; but the primary cause of this shift appears to be the changing economics of agriculture.

In Segment II, the proposed interchange with M-153 poses the greatest danger of adversely changing the ecology of the area. However, this effect can be minimized by proper design of the drainage ditches. The proposed location of the highway in Segment III runs directly through the largest forested wetland in the vicinity. Timber and wildlife cover may be destroyed along the right-of-way and disruption of drainage patterns can also change the character of the forest vegetation through mortality and shifts in patterns of reproduction.

Comparison of aerial photography during the period from 1963 to 1972 indicates that one fifth of the land in agriculture in 1963 changed to idle, extractive, or residential land use. The rate of this kind of change was greatest in Segment I; but this change may have been primarily due to factors other than highway construction. A small amount of residential construction, occurring in the area since 1964, may have been related in some degree to the existence of M-14. There has been practically no increase in commercial activity or industrial development in the area. The actual effects on land use of the construction of M-14 appear to be minor compared to the changes induced by other factors.

The new highway construction in Segments II and III will affect some agricultural areas, and will require the removal of at least six dwelling units. A significant development will be the probable conversion of agricultural and forested land at new interchanges to residential, commercial, or industrial developments.

Additional detail on the assessment of environmental impact at the M-14 Test Site is contained in Section 7.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions concerning remote sensing functions applicable to highway impact assessment are discussed in Section 3.1 and the development status of the necessary technology is reviewed in Section 3.2. On the basis of these discussions, recommendations about future applications and developments of remote sensing as it applies to land use and study are made in 3.3.

3.1. REMOTE SENSING FUNCTIONS

Remote sensing can assist in performing the following functions:

- (1) Collect information on certain types of land use, vegetation categories and species, certain soil properties, and hydrologic characteristics that are of special significance for impact analysis.
- (2) Present this information in special forms for maximum convenience and efficiency in analysis. These forms include generalized terrain or surface feature maps in the form of overlays and enhanced images or recognition maps of significant terrain features or characteristics.
- (3) Produce quantitative data on these land use and terrain factors needed for modeling and prediction of highway impact.
- (4) Provide a continuing source of information to monitor changes in a highway corridor occurring after construction has been completed. This function can be useful for improving our understanding of the influence of the highway on its surroundings and our ability to model and predict changes likely to result from future construction projects.

The following discussion summarizes specific uses of remote sensing and other sources of data for collecting and presenting various types of information.

3.1.1. SOILS

Aerial photointerpretation is a vital part of preparing a soils map. Where an up-to-date soil survey of a highway corridor exists, it constitutes the most comprehensive information base for analysis and prediction of environmental changes. Where such soil survey information is lacking or incomplete, aerial photography or multispectral scanner imagery can be used to complement existing information sources. However, extensive field checking and careful judgment on the part of the soil scientist is necessary to confirm the remote sensing interpretation.

To be widely applicable for impact assessment, any remote sensing technique for directly recognizing and mapping soil characteristics would require the ability to observe large vegetation-free areas at some time during the year. This situation is far from universal but does occur in some agricultural areas. Differences in soils may also be observed indirectly, since these differences are reflected by changes in vegetation. These changes may be observed on aerial photography.

The influence of the soil on environmental changes within a highway construction area is determined primarily by three soil characteristics: texture; natural drainage; and surface slope. Remote sensing methods which may be considered for general use include stereoscopic measurement of terrain slope and interpretation of imagery for identification of textural and drainage characteristics of soils. The remote sensing interpretation of natural drainage of the soil in bare areas is based on the fact that a general correlation exists between soil reflectivity and natural drainage. However, there is a lack of complete agreement, and results derived from remote sensing interpretation should be carefully field checked. Soil reflectivity can be determined both from computer analysis of scanner imagery and human photointerpretation or densitometry of aerial photos.

Within a region it is generally possible to separate bare soil surfaces into five or six groups based on their surface spectral characteristics, using multispectral data. Each group of soil drainage recognized by a single signature may include soils of quite different texture profiles.

Multispectral scanner data can be used to provide information concerning soil drainage, but some ground observation or comparison with soil maps is required to relate the recognition classes produced by the image processing to the actual soil drainage conditions. With these restrictions, the detailed mapping of natural soil drainage obtainable from multispectral imagery can be of use for soil surveys and in highway impact assessment.

3.1.2. HYDROLOGIC CHARACTERISTICS

Remote sensing can contribute several kinds of information to the analysis of hydrologic effects of highway construction. Surface water mapping and observation of soil drainage properties by scanner analysis were performed in this project. Measurements of soil slope and surface drainage patterns provide additional information. Soil moisture measurement by thermal analysis is another possible source of information, but was not tried in this project.

3.1.3. VEGETATION

At least two approaches are possible for the task of studying the effects of highway construction on vegetative cover in the area. One consists of the detailed identification and mapping of

vegetation communities in and near the right-of-way. The effect of the highway can then be assessed from knowing the environmental and economic value of the vegetation, and estimating the probable damage to individual plants or plant communities either directly through destruction or indirectly through the action of highway-associated pollutants, erosion, or changes in drainage.

For this purpose, both aerial photography and multispectral scanner imagery can be used to provide a direct mapping of individual plant communities. Photointerpretation of vegetation species requires scales no smaller than 1:40,000 and requires careful ground checking. Interpretation of scanner imagery also requires careful ground checking but can be performed at scales smaller than 1:40,000. A considerable amount of research has been devoted to spectral analysis for identification of vegetation communities. The prospects for using these methods in impact assessment procedures appear encouraging.

A second approach to the problem lies in preparing a more generalized inventory of vegetation in the area. For this study, a grouping into four major categories of vegetative cover predominating in individual cells of uniform size was used (forest, brushland and mixed types, herbaceous perennials, and annuals or bare). Information on species composition of the plant communities is not recorded in the four-way vegetation map. Such a map allows assessment of damage based on total area of each vegetation category affected, but does not directly identify effects on sensitive species. This is potentially an economical and rapid method of impact assessment, and might be well adapted to the coverage of substantial areas.

The photointerpretation of aerial photography is directly adaptable to the mapping of major categories of vegetation in units of one or more hectares. Scanner processing also shows a capability for classification of vegetation into general categories. Processing results can be presented in an easily reproducible and convenient format. The simpler and more economical methods of classification use ratio processing of two channels of data to provide enhanced images. This technique distinguishes several general categories of vegetation. In the M-14 study, it was able to separate dense forms of vegetation in active cultivation, such as green crops and sod areas, from less dense forms, such as emergent green crops and suburban lawns. These can also be distinguished from deciduous forest and brushland areas. Discrimination of deciduous forests from brushland areas is more difficult, but can be accomplished under appropriate conditions. Diverse groupings of surface water, drainage channels, and poorly drained lowland are designated as another class. In addition to mapping these various types of surface cover, it is possible automatically to measure the fraction of the total area covered by each. Likelihood-ratio processing of more than two channels is more complex than ratio processing, but is more successful at distinguishing vegetation categories.

At the present time, spectral classification methods are not fully developed and continue to require careful checking of computer-generated maps. The vegetation categories recognized on the basis of spectral information differ in some respects from the four categories mentioned above. Also, processing of the data by means of a digital rather than analog computer is required to permit the manipulation and grouping the data into a geographic grid.

For monitoring the effect of past highway construction, both air photointerpretation and multispectral imagery analysis can be used to detect vegetation changes. The interpretation can detect both direct evidence of vegetation damage and the indirect evidence noted from changes in plant communities.

3.1.4. LAND USE

Although the complete assessment of economic and social impact requires consideration of a great variety of factors, remote sensing can provide needed information on those factors related to

- (1) Classifying land use in the highway corridor, by both past and present usage.
- (2) Locating residences, commercial or industrial structures, and other installations which will be directly or indirectly affected by the highway construction.
- (3) Inventorying physical features of the land, as an aid to evaluation of potential uses.
- (4) Monitoring changes in land use.

Preliminary study of aerial photography can serve the important function of guiding and concentrating the assessment effort in the most critical areas. In these areas, remote sensing data on land use and terrain characteristics are also needed for detailed analysis.

Assessment of the direct effects of highway installation on use of land in or adjacent to the right-of-way can be determined from remote sensing without great difficulty. The indirect and long-range effects are much more difficult to predict, since they are influenced by many factors other than the introduction of the highway itself. However, methods of estimating future population and land use trends are already an important part of the process of highway planning, as well as many other planning functions. The application of these methods to the highway impact assessment problem requires the isolation of those growth-inducing factors which can be ascribed either directly or indirectly to the presence of the highway. The full development of impact assessment methods also requires agreement on a set of values for judging the social and economic impact of anticipated changes. Once the methodology has been defined, it can be used to specify the types of data to be provided by remote sensing and other sources on historic and current land use and on some aspects of land evaluation.

3.2. CURRENT STATUS OF REMOTE SENSING DEVELOPMENT

Topographic maps, soil surveys, and air photo interpretation are fully developed sources of information for impact assessment. These sources of information need to be supplemented by field checking and consultation with local officials, particularly in connection with the prediction of social and economic changes which may be induced by the presence of the highway.

The need for up-to-date aerial photography should be stressed if reliable terrain data are to be provided for the analysis. For detailed vegetation analysis, color infrared photography at a scale not smaller than 1:40,000 is highly desirable.

The current method in use by the Environmental Liaison Unit of the Michigan Department of State Highways is based on pinpointing areas of special concern by superposition of maps of terrain features. This method has been further developed in this investigation through the use of remote sensing analysis to provide needed data in a detailed and uniform manner and to present it in a series of overlays providing base maps and various types of thematic maps. Overlay presentation techniques can be used to indicate those areas where highway routes may cause substantial ecological damage. It also displays the relationship of the highway route to land use in the corridor. This form of presentation can be further developed, as the methodology of impact assessment is improved.

Since scanner applications are not as fully developed as air photo interpretation, continuing evaluation of the operational use of scanner data is required. Automatic processing will not replace human photointerpretation, but should prove to be useful for supplying specialized types of information. To take on this duty, multispectral scanner techniques must be competitive with respect to both cost and time with alternate methods of data collection.

The functions for which the use of the multispectral scanner should be considered include:

- (1) Collection of data on natural soil drainage in bare areas where such information is not available from current soil surveys.
- (2) Surface water mapping as an indication of stream channel and drainage patterns in the area and measurement of general soil moisture differences.
- (3) Low resolution mapping of vegetation categories for preliminary impact assessment of highway corridor and routes. Imagery provided by the Earth Resources Technology Satellite (ERTS) may eventually prove useful for this preliminary step.
- (4) Identification and mapping of vegetation species which are specially sensitive to highway construction or air and water pollution.

The demonstration of scanner methods concentrated on those techniques which have been most fully developed. Additional methods of scanner analysis are under development in con-

nection with other projects and should eventually be considered for adoption. These include soil moisture measurement through temperature modeling, identification of soil texture types, use of radar imagery, and mapping of soils, vegetation, and land use from satellite platforms. Improved equipment and methods for scanner data processing are also under development which will improve the accuracy of recognition mapping and reduce the time, effort, and cost needed [1].

The Environmental Liaison Unit of the Michigan Department of State Highways (MDSH) has reviewed the results of the work as they became available and it appears that a number of elements of this research will be implemented. The vegetation classification scheme described in this report and methods of species identification are considered useful techniques. Information gathered by the project on the M-14 Test Site will be used in redesigning the highway's drainage system to alleviate potential ground and surface water problems. RB-57 imagery has been found to be very useful in the impact evaluation process and for route planning as well. Potential uses of the multispectral scanner have not yet been thoroughly explored.

This application study was primarily concerned with demonstrating a number of specific techniques for a particular case. A more encompassing evaluation would benefit from consideration of the relationship of impact assessment to the more general problems of highway corridor selection and route location, since a common set of remote sensing information may be used for these various purposes. Problems of cost-effectiveness of various remote sensing techniques and operational constraints in the application of these techniques also require more thorough consideration than could be applied during the study of a specific case.

3.3. RECOMMENDATIONS

The following actions are recommended toward implementing the results of the impact assessment study.

(1) Clearly defined and readily applicable criteria are needed for assessing effects on biological, physical, and chemical factors of the environment, and particularly on social and economic factors, and a continuing effort should be made toward finding them. Suitable forms of measuring and presenting impact assessment results need to be selected. Allowances of time and cost to be devoted to the impact assessment function need to be specified, since these allowances will affect the economic feasibility of various techniques. The relationship of the function of impact assessment to the related functions of corridor and route selection also influences the adoption of appropriate methods.

(2) The techniques described in this report for collecting, analyzing, and presenting information should be evaluated with regard to their suitability for meeting these operational requirements. The requirements should be expressed in terms of the types, amount, accuracy, and timeliness of information needed for the assessment function. Techniques and procedures for supplying this information should consist of the most effective combination of remote sensing information with information obtained from other sources, such as topographic, geologic, and

soils maps. Data gathering and analysis for impact assessment should be properly coordinated with similar functions for corridor and route selection.

(3) Approaches which economize on both time and funds in the impact assessment process should be further investigated. The process should minimize the need for detailed analysis of individual projects. Models with accurate predictive capabilities, based on the analysis of reliable historical data or experience in specific situations, can simplify and speed up the impact analysis effort. Also, various levels of detail in data gathering and analysis may be appropriate to succeeding stages of corridor and route selection. General analysis would suffice for the initial stages of this process, with more detailed analysis used for assessment of the final route.

(4) Specific remote sensing techniques described in this report should be further evaluated. Analysis of the accuracy and reliability of multispectral methods in recognizing and mapping soil characteristics and vegetation categories and species should be continued.

(5) Further consideration should be given to other remote sensing techniques which were not undertaken during this project. Those additional techniques which appear to be adaptable to operational use after further development should be identified, and needed research to complete their development specified. Remote sensing techniques recommended for further study include the use of thermal modeling for soil moisture measurement, improved methods of identifying soil texture, vegetation mapping based on seasonal changes, multispectral scanner identification of vegetation species that are particularly significant in impact assessment, the use of radar imagery, and low resolution mapping using earth resource satellites.

(6) The applicability of the remote sensing techniques covered in this study for other land resource management functions should be investigated. The types of information and forms of presentation should be considered for a variety of functions, including resource inventory, land evaluation, monitoring of land use trends, site or route selection and project planning.

4
IMPACT ASSESSMENT METHODS

4.1. EXISTING METHOD

Currently, the environmental impact assessment methodology suggested for federal government projects is briefly outlined in Transmittal 202, 24 August 1971, from the United States Department of Transportation, Federal Highway Administration. The method requires a brief description of the area under assessment, a summary of the anticipated positive and negative environmental impacts of the project, a list of organizations whose comments on the statement are requested, and a summary of the comments received.

The focal point of the procedure is the area description and the assessment of impacts. The current practice in Michigan for preparing the area description is to use a set of overlays to record an inventory of the area's resources. Initial generalized corridors for the highway are established, four types of natural features are mapped (vegetation, drainage, relief, and open spaces), and the set of overlays is constructed to designate specific areas of ecological sensitivity.

This sensitivity is thought to be greatest where the location of certain natural features coincide, for example, woodlands and steep slopes. A numerical value system for ecological features is established by using darker areas on an overlay to identify each sensitive natural feature. The values range downward from 4 to 0 to indicate areas highly sensitive with respect to 4 features with diminishing likelihood of ecological damage occurring in the areas marked 3, 2, 1, and 0. This is the basic system used by the Environmental Liaison Unit of the Michigan Department of State Highways to designate and evaluate the ecological impact of such corridors on the existing environment.

At present, highway environmental impact statements use no specific methodology for determining economic and social impact. Projection of changes in land use are derived from the study of available data and as a result of consultation with state and local officials and other persons with knowledge of the impact area. Generally, the data are gathered from existing maps, some field work, and possibly aerial photos. Social impacts are treated as descriptions of such factors as expected displacement of residents, or increased mobility in the labor force. Existing social and economic assessments are nonspecific in character. For example, these statements do not discuss tax base changes, economic pressures for land use change, or even expected land use changes per se. Description of the current economy of the area, its present

land uses, and qualitative predictions of possible adverse or beneficial land use and social effects usually make up the section involving economic and social parameters in current highway impact statements and assessments.

4.2. LIMITATIONS OF EXISTING METHOD

The methods existing at the beginning of this study are under constant review and improvement, but are still in an early stage of development and subject to several limitations.

Certain natural elements or features critical to environmental quality may be overlooked in the assessment method just described. Current maps prepared from up-to-date aerial photographs and other remote sensing imagery have not usually been available for use in impact studies. Dated USGS topographic maps and black-and-white aerial photographs may not adequately show significant qualities and features of the environment. These data sources do not adequately show vegetation, drainage, relief, and open space features, nor other ecological features such as specialized soil groups, prime timber areas, or habitat for various unique fauna. Clearly, one requirement for improved impact assessment is the availability of more relevant and useful data for analysis.

The analysis of environmental data also needs to be further developed. The existing assessment method overlooks the changing patterns of the ecological systems involved. The study of these changes over time is crucial for improved comprehensive impact statements. Also, there is no complete list of the discrete terrain elements which are particularly sensitive to highway installation; neither are there accepted criteria for determining social or economic values of those terrain elements.

To assess properly the changes in the environment which result in land use changes, information is needed on current and historic land use characteristics and the local forces which generate change. A specific methodology establishing explicit data needs and criteria for analyzing and projecting land use changes and potential related problems is crucially needed. The impact statement itself can then be built around specific land use and economic changes that can be expected to occur as a result of highway construction.

4.3. REMOTE SENSING POTENTIAL FOR IMPACT STUDIES

Remote sensing imagery can serve a number of useful functions for highway impact assessment. Intensive application of aerial photography is already a standard practice for certain of these functions. For selecting feasible highway corridors or route locations, aerial photography provides for rapid data gathering in resource surveys, aiding initial identification of unfamiliar areas, and collecting specific landscape information. Aerial photography is also used in preparation of detailed base maps providing the means for indicating the location of

field and laboratory observations, and recording the location and extent of areas with similar soil, forest, land use and other features. However, these general functions of remote sensing need to be focussed on the particular methods of data collection, analysis, and presentation which meet the requirement for impact assessment.

Basically, the highway planner needs two levels of detailed physical information to assess environmental impact. One level of information is derived from generalized up-to-date terrain or surface feature maps of the area of interest. This general level of soil, vegetation or land use information aids the planner in making decisions concerning major ecological and economic/social effects of differing routes for the highway. The second level of information useful to the highway planner is identification of the specific location and extent of minor but socially or ecologically valuable elements of the landscape which are known or suspected to be particularly sensitive to man's activities—elements such as rare plant associations or scenic locations.

Remote sensor data help provide these two levels of information: the information needed for the generalized map and the detailed discrimination of limited scene elements. Regarding the first level, major terrain features, such as forests, cropped fields, bare ground, and surface water, may be discriminated and classified manually by the image interpreter from photos or derived from computer analysis of scanner data. The final data product which provides this type of information may be in the form of hand-drawn maps, annotated photos or photo-mosaics, or computer-classified scene-images of the area of interest. In such presentations areally limited features or subunits of the major surface units are often ignored or combined with other categories. From such data-products, and coupled with specific knowledge or observations of the area, factor maps or images may be derived—such as soil drainage or land-use maps. Thus, in some cases, the generalized landscape information available from remote sensor data and other sources may be useful in itself or it may subsequently be used as a basis for constructing specialized maps.

Another level of information obtainable from remote sensor data and useful to the planner concerns identification and monitoring of minor elements of the landscape which may be subject to particular stress as a result of highway installation. These minor elements of the landscape serve to identify areas to be carefully protected, avoided, or periodically monitored to prevent or reduce the adverse affects of the highway. For example, it would be useful to know the location of areas of aquatic or semiaquatic vegetation which are likely to be affected by changes in natural drainage caused by a highway. Likewise, locations having sediments useful as borrow material should be noted to ensure that, as a result of construction needs, these areas do not become unsightly or dangerous to area residents.

5
SURVEY OF HIGHWAY IMPACT

To provide the necessary background for defining the objectives and procedures for this investigation, this section reviews the more significant effects of the highway on the surrounding environment. It also indicates a number of remote sensing techniques which may be applied to provide needed information either for observing and understanding the effects produced by past highway projects or for predicting the impact of future projects. The discussion indicates the particular remote sensing applications chosen for investigation.

5.1. ECOLOGICAL IMPACT

Highway construction may give rise to several kinds of environmental change. These may be roughly categorized as effects on soils, effects on local hydrology, and effects on vegetation.

5.1.1. SOILS

Chemical and physical properties of soil are often influenced by highway operation. Salt, gasoline, rubber, oil, and other chemicals associated with highways reach abnormally high concentrations in soils on or immediately adjacent to the highway right-of-way. In particular, salt used to de-ice the highway may accumulate in soils near the highway. Sodium and calcium cations entering the soil are adsorbed by negatively charged soil particles; the chloride anion can be leached through the soils and enter the groundwater [2, 3, 4]. Salt concentrations in soils have sometimes been sufficiently high to cause toxicity to plants growing along the highway [5, 6].

Although lead from automobile exhausts accumulates in the soils near the highway, the quantities of accumulated lead are usually not high enough to cause toxicity to plants [7, 8]. The accumulation of cadmium, nickel and zinc in adjacent soils are also attributed to the use of the highways [9]. Although these effects are beyond detection limits of presently existing remote sensors, they must be recognized as potential problems.

The presence of certain soils is also of importance; organic soils make poor subgrades for highways and are usually excavated from the roadway during construction. These materials are generally piled adjacent to the areas from which they are removed, destroying the original vegetation and changing the composition of the plant community.

Where an up-to-date soil survey of a highway corridor exists, it constitutes the most comprehensive information base for analysis and prediction of environmental changes. The M-14 Test Site is an area in which a soil survey has been completed, and the information was used

extensively in the study. However, it was of interest to determine the manner in which aerial photography and multispectral scanner imagery is capable of providing this basic information in areas where soil maps are unavailable. More generally, remote sensing information should be considered as a means of contributing directly to the soil survey process.

The influence of the soil on environmental changes within a highway construction area is determined primarily by three soil characteristics: texture, drainage, and slope. Both scanner imagery and aerial photography were concentrated on observing and mapping these characteristics; photography and scanner data being applied to the task of identifying and mapping soil drainage and texture, while slope information was taken from existing soil maps and also by stereoscopic measurement.

5.1.2. HYDROLOGY

The construction of a highway may have widespread effects on both surface and subsurface hydrology. Alterations of natural drainage and runoff patterns can cause excessive channel erosion and sedimentation, flooding during periods of high rainfall or snowmelt, and local raising or lowering of the water table. Roads constructed across drainage basins may act as a barrier to flow, causing a rise in the water level and perhaps flooding on one side, with dry conditions on the other. Changes in the stream network can cause the depletion of existing natural impoundments (ponds, lakes) and/or the creation of new ones.

Paving of the highway covers large areas with materials impervious to infiltration of water, and roadway wash effluent often extends this sealing effect to adjacent improved surfaces. The net result may be a substantial increase in surface runoff and correspondingly reduced capacity for groundwater recharge. Both of these effects induce greater variations in streamflow by affecting both maximum and minimum flows.

Although good surface drainage is necessary to maintain a major highway, ditches constructed along the highway for this drainage may lower the natural water table in areas of somewhat poorly drained and poorly drained mineral soils. In other areas, the highway may act as a barrier to the movement of subsurface water, raising the natural water table or causing stagnant conditions unfavorable for plant growth. The highway may also block surface water drainage resulting in pond formation.

Destruction of wetland areas interferes with many functions beneficial to the environment. In addition to providing suitable habitat for many forms of wildlife, these areas act as a means of purifying and oxygenating the water supply, as collection basins for groundwater recharge areas, and as reservoirs to stabilize streamflow.

Interpretation of both aerial photographs and scanner data is useful for studying drainage patterns before and after highway construction. Surface water can be mapped using level slicing of one of the near-infrared channels of scanner imagery to delineate drainage patterns and water table level.

Patterns of soil moisture distribution may also be studied by observing the darkening effect of high soil moisture content on the tone of bare soil. The moisture content of soil has a significant influence on the amount of energy reflected from the soil; as the moisture content increases, the reflectance decreases [10, 11]. Immediately after a rain, reflectance from soils decreases, but increases as the soil drains. If the rain produces a crust on the soil, the reflectance will be greater than if no crust had formed. Therefore, reflectance from soil depends not only on soil properties but also on the amount and intensity of rain and on the length of time since the rain.

The use of thermal mapping to measure diurnal temperature variation is another method of determining soil moisture; smaller temperature variations are associated with high moisture content. This technique is under investigation in other projects and was not applied in the M-14 study.

Soil exposed during highway construction has an increased susceptibility to water erosion. Eroded sediment from such areas is deposited below the construction site during periods of runoff. Once the sediment is deposited in a stream channel, it reduces the cross-sectional area of the stream causing stream bank erosion during periods of high runoff. Moreover, the volume of this runoff will be greater than that prior to construction not only because of the paving of large areas but because soil compaction by the heavy construction equipment decreases infiltration and permeability of the soil. Thus, the additional runoff puts added stress on a stream causing its channel to widen. Eventually, soils adjacent to the stream may be flooded more frequently by the greater runoff, or they may be eroded by the stream due to widening of the channel.

In one study, it was observed that highway construction covered about 11% of the watershed drained by Scott Run in Fairfax County, Virginia [12]. These construction areas were shown to contribute 85% of the sediment deposited in the basin's stream system. The amount of sediment in the stream correlated well with the size of the area under construction. The amount of sediment produced by erosion from highway construction sites was about 10 times greater than that from cultivated land, about 200 times greater than that from grassland, and about 2000 times greater than that from forest land.

Borrow pits are produced by excavation for highway construction. If excavation extends below groundwater level, the pit fills with water for at least some portion of the year. Borrow pits which do not extend below groundwater level may be a source of stream sediment for as

many years as they remain exposed. Unless vegetation cover which prevents erosion is planted, they quickly become unsightly, attracting trash and pests.

Some highway salts enter streams as a result of runoff from the surface [2, 13]. Research has shown that salt concentrations of some streams increase significantly as a result of highway snow clearance operations [13, 14]. The salt concentration of lakes into which these streams flow also increases [13] and may prevent complete vertical mixing during the spring [15]. Thus, an impairment of water quality may be associated with highways as a result of salt and sediment in the runoff.

Aerial photography, particularly conventional color photography, and multispectral scanner data can be used for observing sediment suspended in streams and lakes. In addition, scanner processing techniques are under development which may provide quantitative measurements of sediment concentrations. This use of remote sensing would be applicable to observation of conditions occurring during or after highway construction.

5.1.3. VEGETATION

The potential impacts of highways on vegetation can be placed in three categories. First, the physical injury and exposure that result directly from the construction work are virtually unavoidable, since clearing of the right-of-way is essential. Changes in site quality as a result of highway construction make up the second category. The severity of these impacts depends upon the care and ecological insight used in designing and constructing the highway. The third category consists of the effects of highway pollutants on roadside vegetation. The major pollutants are de-icing chemicals and exhaust emissions which may induce both acute and chronic effects on roadside vegetation, though species do vary in their tolerance to such pollutants.

The most obvious destruction of vegetational communities comes with the initial clearing of the right-of-way. Given a freeway with four 3.6 m (12 ft) lanes and 15 m cleared on either side of the pavement, a swath of approximately 45 m is cleared, even with no median strip. This means that 4.6 hectares of the native vegetation is removed for every km of freeway (17 acres/mile); the very minimum effect of freeway construction. However, the damage to vegetation does not stop with the 45 m strip. If the road goes through woodland, for instance, the root systems and boles of trees at the edge of the cleared strip sustain some injury from the heavy equipment used in clearing and grading. While some damage to marginal vegetation is unavoidable due to limited maneuverability of the equipment, injury can be limited if the equipment operators make a deliberate effort to do so.

Even without direct physical injury, however, the trees at the edge of the strip are exposed to sunscald and wind where they were previously protected by adjacent cover. This results in a loss of vigor from the effects of exposure and possible windthrow. The reduced vigor in-

creases the susceptibility of the trees to attack by insects and diseases. Many of these insects and diseases tend to establish a center of infection in the low-vigor individuals, and spread later to healthier plants.

The method of disposing of cleared materials is also important. Where they are simply piled and left to rot, the materials may serve as infection centers for build-ups of insect and disease outbreaks. Burning is the easiest method of disposal, but heat and fumes often damage the adjacent vegetation. This in turn increases susceptibility and contributes to the general decline.

In the absence of insects and disease, and given favorable weather conditions, a gradual recovery of the residual vegetation occurs. The exposed edges are closed by the growth of shrubs and seedlings, and mortality may be limited to the few individuals which received the most severe exposure. Thus, damage following construction is determined by the previous vigor of the plants, weather conditions, the presence or absence of insects and disease in the area, and the care taken in the clearing operation [16, 17].

The second category of potential impacts of highway construction on vegetation involves alterations in site quality. Site quality is the term used to express the sum total of the physical factors of the environment. Soil and moisture are the main factors, and are closely interrelated. Alteration of natural drainage patterns can have disastrous effects on the wetland plant community, and should be avoided in highway construction whenever possible. When crossing wetlands is unavoidable, the highway design must be formulated carefully to preserve the natural drainage patterns. This may mean installing crossing culverts every 30 m. Careful replacement of topsoil and avoidance of indiscriminate dumping of spoil from cuts further minimizes impacts. With shallow rooted tree species, wind patterns must also be considered if extensive windthrow is to be avoided.

The third category of vegetational impacts covers long term effects of de-icing chemicals and exhaust emissions on vegetation. The most prevalent de-icing chemicals are sodium chloride and calcium chloride salts. The effects of de-icing salts on vegetation have received considerable attention [17-20], and the damage and mortality caused by them is a well documented fact [18]. However, different species vary widely in tolerance to salt effects and these effects are usually limited to the immediate vicinity of the right-of-way (approximately 15 m on either side) where high concentrations develop. In general, evergreen trees and shrubs are much more sensitive to salt than deciduous species because evergreen foliage is exposed during the winter salt season. Studies of Michigan freeway plantings relate that replanting was required for 40% of the pine trees examined [16]. Many deciduous trees, especially maples, are also sensitive to the effects of salt. Although grasses are more tolerant of salt than trees and shrubs, salt does reduce germination, stand density, and growth.

Damage from exhaust emissions is more subtle than salt damage. Most of the trouble is traceable to oxides of nitrogen and hydrocarbons where photochemical reactions transform these emissions into toxic pollutants, ozone and PAN. These can induce a variety of symptoms not easily separated from the symptoms caused by insects, diseases, drought, and nutrient deficiencies. As with salt injury, evergreens tend to be more sensitive to air pollution among the trees, particularly so for eastern white pine.

Up to this point, we have been considering potential impacts of the highway on plants and plant environment. There is also a good deal to be said about the potential impacts of plants on the highway environment. On the negative side, large trees immediately adjacent to highways tend to increase personal injury and property damage in accidents where the car leaves the road. Since trees immediately adjacent to the road are likely to suffer salt injury anyhow, the practice of removing all trees within 15 m of the pavement along freeways is well advised. Plant communities on the right-of-way should be salt-resistant grasses and shrubs. Vegetative cover is essential to prevent erosion and water pollution; therefore, horticultural efforts must be accepted as part of the cost of constructing and maintaining any highway.

For adjacent vegetative communities, the goal, from an ecological standpoint, should be to disturb these communities as little as possible. Particularly in the case of forests, these communities provide real benefits to both motorists and residents of the surrounding area. Trees act as windbreaks to reduce potentially dangerous gusts across the highway and drifting of snow, and are effective as sound barriers in reducing noise pollution from the highway. Plants of all types help to clear the air of both particulate and gaseous pollutants at sublethal levels. In addition, the aesthetic contribution of the vegetation is obvious.

Another factor to be taken into account is the influence of the highway installation on wildlife habitat. The destruction or modification of vegetative cover and changes in wetland areas due to modifications of drainage patterns constitute a threat to various forms of wildlife. Prediction of changes in these terrain features as they affect wildlife is thereby a part of the impact assessment process.

From this discussion, it is apparent that information on the location and composition of vegetative communities is essential for the process of highway planning. At least two approaches are possible for the task of studying the effects of highway construction on vegetative cover in the area. One approach consists of the detailed identification and mapping of vegetation species in and near the highway right-of-way. The effect of the highway can then be assessed from a knowledge of the environmental and economic value of the vegetation and estimating the probable damage to individual plants or plant communities either through direct destruction or indirectly through the action of pollutants or changes in drainage. For this purpose, both aerial

photography and multispectral scanner imagery can be used to provide a direct mapping of individual species or communities of plants.

A second approach to the problem lies in preparing a more generalized inventory of vegetation in the area, recorded in four major categories of vegetative cover predominating in resolution elements of uniform size, say 2 hectares. Assessment of damage can be based on evaluation of total effect on each cell. The use of 4 major categories of vegetation without specification of individual species permits a general estimation of the area of vegetative destruction, but does not directly identify effects on sensitive species unless supplemented by other records. The photointerpretation of aerial photography is directly adaptable to the mapping of major categories of vegetation in sizable cells. Multispectral scanner techniques might also be used, but the full adaptation of computer recognition methods for this purpose requires additional development and demonstration of appropriate techniques.

Monitoring of the effect of past highway construction can be performed by detection of vegetation damage. Both air photo interpretation and analysis of multispectral imagery can be adapted to this purpose. The interpretation should detect both direct evidence of vegetation damage and the indirect evidence noted from changes in plant communities.

5.2. LAND USE IMPACT

The full assessment of the economic and social impact of the construction of a highway along a specific route requires the consideration of a wide variety of economic, social, and demographic information, as well as data on the current land use and physical characteristics of the terrain [21]. A thorough treatment of social and economic cause and effect is beyond the scope of a study concerned with remote sensing applications. The treatment of this topic is therefore limited to the economic and social considerations closely associated with land use and land use changes adaptable to inventory and evaluation. Although there is need to examine in depth the consequences of highway construction on the displacement of persons, the splitting of land parcels, the change in economic return from property, the change in social character of neighborhoods and many other considerations, this investigation was limited to two elements: (1) the identification of current land use (and historic land use where imagery is dated and usable), and (2) the most discernible changes in land usage over time.

A highway construction project has both immediate and longer range effects on land use. There is a direct change in the use of land acquired for highway right-of-way. The use of adjacent land is also affected, through alteration or restriction of access. Such lands where access will be restricted are frequently acquired by the MDSH as excess property, and either held idle or used as borrow or deposit pits.

Other land, which will experience increased access because of its proximity to a major intersection, feels pressure for use in a higher economic return category than before the highway was put through. The pressure to change, resulting directly from highway installation is therefore both economic and physical.

Land use in the general vicinity of but not physically touched by the highway is also subject to influence. The change in land use to be expected here is generally tied to the increased access gained to the area or region. Such secondary effects may be as much the result of changing area-wide economic patterns, tax shifts, population gains, and development programs as they are the result of the highway construction. Assessment of cause and effect concerning the interrelation of these factors becomes very speculative. Many investigations have attempted to assess the impact of new or improved highway facilities on a community, with special consideration given to changes in land value, traffic patterns, business volumes, and personal or community reaction to the change in highway facilities. An excellent study of this type is found in Ref. [22].

Although the complete assessment of economic and social impact requires consideration of a great variety of factors, remote sensing can provide certain information on those factors related to

- (1) Classifying land use in the highway corridor, by both past and present usage
- (2) Locating residences, commercial or industrial structures, and other installations which might be directly or indirectly affected by the highway construction
- (3) Inventorying physical features of the land, as an aid to evaluation of potential uses
- (4) Monitoring changes in land use

The feasibility of using such remote sensing data depends upon the type of prediction attempted. Methods of determining from aerial photography the needed relocation of residences and the probable effect of dissecting parcels of agricultural and other land are relatively straightforward and in current use. Guidelines are now available for calculation of highway traffic noise as a function of distance from the highway, total highway traffic, and other variables. With the aid of air photo interpretation, these guidelines can be applied to determine the unfavorable impact of such noise on existing residences along the projected right-of-way and the extent of areas adjacent to the right-of-way which might be affected in the future.

The more complex problems of predicting future changes in land use and metropolitan growth along the highway route are less easily resolved by remote sensing. Preliminary study of aerial photography can help to guide the impact assessment effort and concentrate it on the most critical areas. Remote sensing data on land use and terrain characteristics is also needed in the ensuing analysis.

Because of the complexity of the analysis of the interrelated factors affecting economic and social impact, a full treatment of the problem is outside the scope of this investigation. However, the work reported in Section 7 illustrates the use of aerial photography in assembling and analyzing data on past land use changes and current land use which are an important part of such impact assessments.

6
INVESTIGATION PROCEDURES

The overall purpose of the studies at the M-14 Test Site was to determine how the use of remote sensing techniques can contribute to the highway planning process, in particular, the assessment of environmental impact. The highway problem is representative of a whole class of large scale construction problems. While the intensity of concern with the various aspects of the problems differs, many of the elements of the highway problem are common to the planning and construction of any utility system.

6.1. OBJECTIVES AND METHODOLOGY

A number of specific objectives for this study evolved as a result of frequent meetings among personnel of MSU, ERIM and the MDSH Environmental Liaison Unit. Specific objectives were as follows:

- (1) To make up-to-date vegetation, soil characteristics, surface water system and land use maps for the study area by means of computer-processed multispectral data, aerial photography, ground truth collection and generally available published data sources.
- (2) To determine changes which have occurred in terrain, vegetation, soils, the surface water system or land use over the previous decade in the study area.
- (3) To hypothesize those changes in the terrain, vegetation, surface water system, and land use which can be expected to occur in the proposed highway impact area over the next several years.

Two major phases of the utility or highway planning process remain once the need for such a facility has been determined, namely, location analysis and environmental impact assessment. These two phases should be closely interrelated and interactive. An inventory of resources existing in the area of interest provides the basis for both location analysis and impact assessment. This inventory must include both the natural and cultural environmental components. Any attempt to subdivide an ecosystem into components must be somewhat arbitrary, but the following breakdown seems reasonably natural as well as utilitarian:

- Component I - geology, soils, and hydrology (physical resources)
- Component II - vegetation (flora)
- Component III - wildlife (natural fauna)
- Component IV - socio-economic (human populations and land use activities)

This classification structure has been used as an operational breakdown of resource types throughout the project, and is evident in the structure of this report. Because of the difficulties associated with direct observation of wildlife by remote sensing, that category has not been treated specifically. However, the analysis of changes in land use, vegetation, and water distribution can be used for the assessment of anticipated changes in wildlife habitat.

6.2. SITE SELECTION

The M-14 Test Site is an area north and northeast of Ann Arbor, Michigan in Washtenaw County (see Fig. 1). The present M-14 highway includes a 5 km portion of 4-lane freeway constructed in 1964 just north of Ann Arbor and continues northeast along 2-lane Plymouth-Ann Arbor Road to Plymouth, Michigan [23]. The portion of the route along Plymouth-Ann Arbor Road will be relocated to a 19 km 4-lane limited-access extension to be constructed by MDSH during the period 1973 through 1975. The study area presently consists largely of agricultural and natural areas including extensive wetlands and woodlots, and is defined by the Fleming Creek watershed and other hydrological boundaries. The Fleming Creek watershed is crossed by the present freeway and the planned extension.

The project staff, in consultation with the Michigan Department of State Highways, selected this area for study because its characteristics meet many of the requirements desirable for a study area:

- (1) Construction activity at this site is imminent; therefore, the area is one of current interest to MDSH.
- (2) The site is an extension of a recently constructed segment of freeway, so that the ecological effects of the existing highway segment can be studied as an index to the probable impacts of the proposed segment.
- (3) The situation is reasonably typical of other instances throughout the State of Michigan where highway construction is planned, so that the applicability of the results should be broad.
- (4) Recent soil survey information is available for the site.
- (5) A number of sources of aerial photography were available for study.

The M-14 Test Site was divided into three segments for purposes of the study. Segment I consists of the existing M-14 freeway constructed in 1964 between Nixon Road and Vorhies Road. This segment provides the desired opportunity to study the environmental impact of a recently constructed highway, and studies of this area serve to guide the predictions of impact for the proposed section. A strip approximately one kilometer wide on either side of the highway was chosen because physical impacts of the highway would be most appreciable within that range.

Segment II adjoins the first at Vorhies Road and extends to Murray Lake. This section includes the proposed interchange of M-14 freeway with M-153, as well as that portion of the proposed freeway extension that parallels the existing Plymouth-Ann Arbor Road. The freeway will continue eastward through Segment III, which abuts Segment II and extends slightly to the east of Gottfredson Road. This is a relatively undisturbed wooded wetland within the Fleming Creek drainage basin.

6.3. SENSOR SELECTION

Since aerial cameras are the most widely used and most readily available sensors, aerial photography was extensively used in the study to provide photographic coverage before, during, and after highway construction. Aerial photography also provided the basis for assessing the role of the multispectral scanner. Testing efforts for advanced remote sensors were concentrated on the M-7 twelve-channel optical mechanical line scanner mounted in a C-47 aircraft and operated by ERIM. With NASA support this system was designed and constructed by ERIM and has been operational since 1971.

Photographic and multispectral systems in many ways represent complementary remote sensor systems and data collected from one may be used to augment and enhance information extraction from the other. Conventional methods of photographic interpretation rely on the detection and identification of scene elements by a human interpreter who uses accumulated experience and knowledge of the spatial and geometric characteristics of objects to classify the terrain. The strong contrast and high resolution qualities of aerial photographs are well suited for this purpose. The multispectral scanner system uses the information content of a large number of spectral bands operating in the ultraviolet, visible, reflective infrared, and thermal infrared ranges to recognize and map terrain features on the basis of their unique spectral characteristics. It can also observe and map variations in surface temperature or emissivity, which can be related to such phenomena as vegetation condition, soil moisture content, and water circulation in lakes and streams. The interpretation of multispectral scanner output data is dependent on the use of computer-aided analysis techniques, which have a potential for rapid and automatic data processing.

The study made extensive use of high-altitude aerial photography acquired by the NASA RB-57 aircraft over Southeast Michigan in 1969, 1970 and 1971. Duplicate positive transparencies of 9 in. \times 9 in. color-infrared and natural color film provided sufficient resolution for interpretation of vegetation, soils, and other material and cultural features. The use of color film substantially increased the interpretability of the photography.

6.4. MULTISPECTRAL SCANNER DATA COLLECTION

Multispectral scanner data were collected from a total of ten flightlines over the M-14 Test Site on two flight mission dates. Data were collected with the M-7 multispectral scanner with twelve channels covering a range from $0.33\ \mu\text{m}$ (ultraviolet) to $11.7\ \mu\text{m}$ (thermal infrared). Although the two missions spanned only a one month interval, considerable seasonal change in both vegetation and surface hydrology occurred during this period. Extensive ground observations were also made during and subsequent to the remote sensing flights.

Mission 54M was flown over the M-14 Test Site on May 5, 1972, with the NASA-supported C-47 aircraft. Two flightlines were flown at 2100 m (about 7000 ft) altitude covering the Fleming Creek watershed and two at 600 m (about 2000 ft) altitude, one over the existing M-14 freeway and one over the proposed extension. Mission 57M, flown over portions of the area on June 5, 1972 in conjunction with another investigation, also provided useful scanner and camera data for analysis. Six flightlines were flown at 600 m above the M-14 study site. Two rectangular detailed study areas, 10 km by 3 km and 5 km by 3 km were recorded on contiguous flightlines. Flight conditions were excellent for the collection of multispectral data on this date.

The full potential of multispectral scanner systems is realized by means of special automatic processing instrumentation. Information is included in Section 8 on the multispectral data processing methods used in this investigation

6.5. AERIAL PHOTOGRAPHY

Because of its widespread use, conventional aerial photography accounted for most of the existing imagery covering the M-14 Test Site. These photographs came in a wide variety of forms, none of which was ideally suited to the present purposes:

(1) Panchromatic paper prints in 9×9 in. format (22.9×22.9 cm) at a nominal contact scale of 1:20,000 were obtained from the Agricultural Stabilization and Conservation Service. This photography was collected on 21 May 1969.

(2) Panchromatic paper prints similar to those above, were obtained by the Michigan Department of State Highways from Abrams Aerial Survey. These photographs were obtained in three separate missions in 1963, 1967 and 1970.

(3) Color infrared positive transparencies (9×9 in.) were taken from the NASA RB-57 aircraft with a Wild-Heerbrugg RC-8, 15.3 cm focal length camera in 1969. The scale of these photos varies somewhat, but approximates 1:120,000. The mission was planned for complete stereo coverage on the 15.3 cm RC-8 camera.

(4) Color infrared transparencies (9×9 in.) were taken with a Zeiss metric camera equipped with a 30.5 cm focal length lens, at a scale of approximately 1:60,000. These

photos were taken during the same RB-57 mission as the color infrared imagery in (3) above. With the smaller field of view of the Zeiss camera, stereo coverage was not complete for the 1:60,000 color photography.

(5) Black-and-white infrared photography (9 × 9 in.) was collected during C-47 scanner flights of May 5, 1972 and June 5, 1972. The May photography in the 9 in. format was of marginal utility for several reasons. It was of poor quality, and constraints placed on the flight by the scanner flight requirements resulted in incomplete coverage and variations in scale. The June photography was of better quality.

(6) Color infrared positive transparencies (70 mm) were also collected in conjunction with the two scanner missions. Again, the May photographs were marginally useful. In this case, the difficulty arose from the use of an improper filter and lens combination. Excessive distortion and color imbalance hindered proper photointerpretation. The 70 mm color infrared photography from the June mission was of good quality.

6.6. GROUND TRUTH COLLECTION

Ground-based observations made in support of remote sensing activities included the collection of specific field data at the time of or subsequent to remote sensor missions and the study of maps, reports and other available information concerning the area. Ground truth was used to provide four services to the image interpreter: (1) spot verification to assure correct image interpretation or computer recognition, (2) identification of unusual objects or patterns, (3) aid to the interpreter in discovering uses or relationships not readily apparent to the imagery, and (4) assistance to multispectral scanner processing personnel in selecting training sets for computer-based processing.

Ground truth was collected just prior to, during, and after the 5 May C-47 data collection mission. To provide for calibration of the multispectral scanner outputs, six large panels with known spectral reflectance characteristics were deployed at a point along one of the flight-lines.

For collection of information on vegetation, a series of roadside transects were made in both west-east and north-south directions. Vegetation types on both sides of the road were described orally, and recorded on tape. In addition, photographs were taken at intervals providing visual records of developmental stages of the vegetation.

Soil training sites needed for multispectral scanner processing were located in bare soil fields or sparsely vegetated fields on the day of the multispectral scanner flight. Soil observations were made to identify the soil at each site. Samples of the upper several millimeters of soil from these sites were taken into the laboratory for soil moisture determinations on the day of the flight. Reflectance measurements of soils at some training sites were made on the day

of the flight with an ISCO portable field spectroradiometer. Also measurements of soil and surface water temperatures were made with a portable radiometer.

Ground truth collection also included the assembly of recent soil maps for Washtenaw County. Field transects made by P. E. Davis of the Michigan Agricultural Experiment Station [24] determined the average soil composition for mapping units within the Fleming Creek watershed.

At the completion of processing and interpretation of the aerial photography and scanner imagery, the interpretation results were further verified. Agency liaisons equipped with cartographic interpretations of land use and vegetation imagery consulted with local persons generally regarded as knowledgeable about changes which have occurred in the area. These persons checked the maps on a plot-by-plot basis to ensure their accuracy and to predict vegetation and land use changes which would most likely occur within the next decade. Their forecasts were generally of two types. First, the amount of land devoted to agriculture within the study area will greatly decrease, being replaced by subdivision developments; second, much of the unused land and gross areas, shown on vegetation maps, if undisturbed, will naturally evolve into brush land within 5-10 years.

6.7. PHOTO INTERPRETATION AND CARTOGRAPHIC PROCEDURES

Interpretation of the available aerial photography was used as a major source of information on land use and terrain features. For the impact assessment process, this information was transferred to a set of base maps and overlays. These overlays can be viewed singly or superimposed to show interrelationships of terrain features. In addition to demonstrating its primary use, maps of the M-14 site were prepared so as to function as an effective visual aid for conducting seminars and workshops for various interested agencies. Procedures for photographic interpretation and preparation of these cartographic products are described in this section.

The following equipment was used in photo reading: Abrams pocket stereoscope; 3-8x Wild-Heerbrugg mirror stereoscope; and 4x hand lens. Most interpretation was accomplished with the mirror stereoscope, with a portable light table for a light source. The interpretation of imagery was restricted to some extent by limitations of available equipment and in some cases by image quality.

The features identified through the interpretation of photographs were transferred to the cartographic product by the construction of overlays from the photos. A base map was drawn at a scale of 1:24,000 for each of the three study areas. Sepia copies of these maps were made and distributed to the photo interpreters as work maps. Transparent overlays were placed over the photos and type lines or land use features were recorded. Reference points, such as

roads and lakes, were also included to aid in transferring information to work maps. Following construction, the overlays were enlarged to the size and scale of the work maps. The reference points were used to ensure proper enlargement. The data on the overlay were then transferred to the work map. Since the work maps were at the same scale as the final map, the cartographers could simply trace the information from the work map.

For enlarging the photographic overlays to the scale of the work map, a Model 55 Map-o-Graph enlarger and a Keuffel and Esser enlarger were used. Because of the basic design of these (and most) enlargers, optical distortion occurs increasing radially. Thus, the larger the base map (length and width) and amount of enlargement of the photo overlay, the greater is the distortion. (Since the enlarged image is fairly accurate at a small area in the center of optical projection, adjustment of either the map or overlay will help alleviate the distortion.) The Keuffel and Esser enlarger was equipped with a tilting stage, which adjusted the overlay. The reference points for control allowed the image to be adjusted to alleviate some of the distortion problem. Some overlays involved an enlargement of about 4 times. Thus, even with a tilting stage, distortion occurred during enlargement. All photographs have the same optical distortion as the enlargers. Some photo mosaics used had only alternate flightlines, which necessitated matching the edges of the photos. With only about 10% overlap, distortion occurred in the mosaic overlays prior to enlargement. These distortion problems, in both enlarging and in the photographs themselves, somewhat impaired the accuracy of the final cartographic products.

For the overlays, all maps were drawn in black ink, screened and patterned on mylar with two duplicating processes. Lithographic plates were made of each map so that they could be run off inexpensively on paper in black and white. In addition, a set of plates was reproduced by a diazo process to produce acetate transparencies in pre-determined colors. The transparencies are durable, can be used with or without an overhead projector, and provide an effective visual representation.

The patterns symbolizing different resource features were selected so that the crucial factors adversely affecting the highway location could be rendered in darker shades. In each case the scale used was 1:24,000 and each map was produced on 8 1/2 x 11 in. sheets.

The M-14 area was divided into three map segments corresponding to the individual study areas. For each segment, a base map encompassing a corridor approximately one km wide along either side of the existing or proposed route was drawn. Included on this base were the road networks, primary surface drainage features, and the Universal Transverse Mercator Grid.

For each of the three segments, maps were drawn to display topography (with contour lines from the USGS quadrangle), vegetation, land use, surface slope, soil profile texture, and natural

drainage of the soils. For the transparencies, a base map was printed on acetate in black for each segment and an overlay in a specific color was produced for each factor mapped. This method permits visual representation of the interrelation of factors.

ANALYSIS OF ENVIRONMENTAL IMPACT

The results of the analyses completed on the M-14 Test Site are presented in this section: the benchmark inventories of natural and cultural features, the assessment of changes occurring over the last decade, and some predictions of likely effects on the environment caused by the further extension of the M-14 freeway.

It is important to keep the objectives of the study in mind; the target has been an application and evaluation of the utility of remote sensing in compiling inventories and change analyses for highway impact studies. Thus, no complete impact statement is presented here, but rather a description of those elements for which remote sensing appears to present an immediate and evident improvement on current techniques.

The impact assessment technique described in this section and in use by the Environmental Liaison Unit of the Michigan Department of State Highways requires the identification of areas with different levels of sensitivity of soil, water, vegetation, and cultural features to adverse influences. The use of a set of overlays to map and compare these features provides a rapid and convenient means for making this determination. A number of the figures in this report have been prepared by superimposing soils, vegetation, or land use overlays on the base map. The overlays have also been separately produced in complete sets, as described in Section 6.7.

This section does not directly discuss the use of multispectral imagery as a source of information for analysis of the M-14 Test Site. The subject is covered in Section 8.

7.1. SOILS AND WATER RESOURCES ANALYSIS

The characteristics of the soil resources in the study area are more likely to affect the design of the roadway than they are to be affected by its presence. Factors of soil texture, natural drainage and slope all add to the complexity of highway route selection, and should be considered in impact assessment as well.

7.1.1. DEFINITIONS OF SOIL CHARACTERISTICS

The soil resource inventory for the M-14 corridors was generalized from the soil maps prepared as part of the National Cooperative Soil Survey of Washtenaw County. The soil profile and landscape characteristics most important to land use are the profile texture, natural drainage, and slope of the soil surface. These characteristics are defined for the M-14 Test Site as follows.

Soil Texture

The soil profile texture refers to the average sand, silt and clay content of the upper 150 cm of soil materials. The texture categories within the study area are as follows:

Coarse texture—The coarse textured soils have an average profile texture of loamy sand or sandy loam. Within this study area, most of these soils have sand or sand and gravel between 50 and 150 cm in depth. These soils have a moderate to rapid permeability.

Medium texture—The medium textured soils have an average profile texture of loam or silt loam. A small amount of these soils have 50 to 100 cm of loamy sand or sand materials over the loamy materials. Because the topsoil is removed during construction of a major highway, these latter soils will react more as medium textured soils than coarse textured soils. The soils in this category have a slow permeability.

Fine texture—The fine textured soils have an average profile texture of clay loam, silty clay loam, clay or silty clay. These soils have a very slow permeability.

Organic—The organic soils are composed of more than 20% of organic matter. Some of the organic soils in the study area are underlain with sand below 40 cm.

Soil Drainage

The natural drainage of the soil refers to the height and annual duration of the natural water table in the soil. The water table is the level below which the soil is saturated with water. This evaluation does not consider artificial drainage. The natural drainage categories within the study area are as follows:

Well and moderately well drained—The water table does not rise above 75 cm for any appreciable length of time.

Somewhat poorly drained—The water table fluctuates; it is near the soil surface during the winter and spring and may be below 150 cm in late summer and early fall.

Poorly drained—The water table is near the soil surface for a considerable part of the year. The water table may be deep in the profile in late summer and early fall.

Organic soils—The water table remains at or near the soil surface throughout the year.

Alluvial soils—These soils have a high water table throughout most of the year and are subject to flooding. These soils are located along streams; they have developed in recently deposited materials that are frequently stratified.

Soil Slope

The slope of the land surface is expressed in the gradient or percent slope of the soil surface. The percent slope is equal to the number of meters rise or fall of the land surface for each 100 m of horizontal distance. The slope categories within the study area are as follows:

- 0 to 6%—level to gently sloping
- 6 to 12%—rolling or moderately sloping
- 12 to 18%—hilly or strongly sloping
- 18 to 40%—very hilly or steeply sloping

The 1:15,840 soil maps prepared by the National Cooperative Soil Survey have greater detail than the 1:24,000 generalized soil maps prepared from them. Special symbols are used on the former maps to indicate small areas which are more poorly drained or which are more steeply sloping than the mapping unit delineation. These maps also show the natural and some man-made drainageways. These features were not indicated on the generalized maps because of the smaller scale.

Comparison of the generalized soil maps in the following illustrations was made with field observations at 429 points on transects in the Fleming Creek watershed. The average profile texture of the soil maps agree with that of the observations 89% of the time. The natural drainage class of the soil maps agree with that of the point observations in 68% of the cases. The percentage of slope of the observations was within the range of the slope class of the soil maps in 82% of the cases.

7.1.2. SOIL AND WATER CHARACTERISTICS OF THE AREA

The soils in the existing M-14 freeway corridor (Segment I) range from loamy sand to clay in average profile texture. Medium- and fine-textured soils predominate in the western portion of this corridor (Fig. 2). Coarse textured soils predominate in the extreme eastern portion of Segment I, with small areas of organic soils scattered throughout but not in the path of the highway. The soils of this test site are primarily well and moderately well drained with smaller amounts of somewhat poorly drained and poorly drained soils, but the existing M-14 freeway is primarily located on well drained and moderately well drained soils (Fig. 3). The existing M-14 corridor is mostly gently rolling in nature, with only scattered areas having greater than 12% slope. Some areas outside the proposed right-of-way exceed a slope of 12% (Figs. 4 and 5).

The soils in Segment II, the western portion of the proposed corridor containing Frain and Murray Lakes, are mostly coarse textured with medium and fine textured soils located a short distance from and on both sides of the proposed M-14 route (Fig. 6). Organic soils are located in this area, but not in the path of the highway. Thus, the excessive costs and ecological impacts associated with dissecting or removing these deposits have been avoided. Although well drained

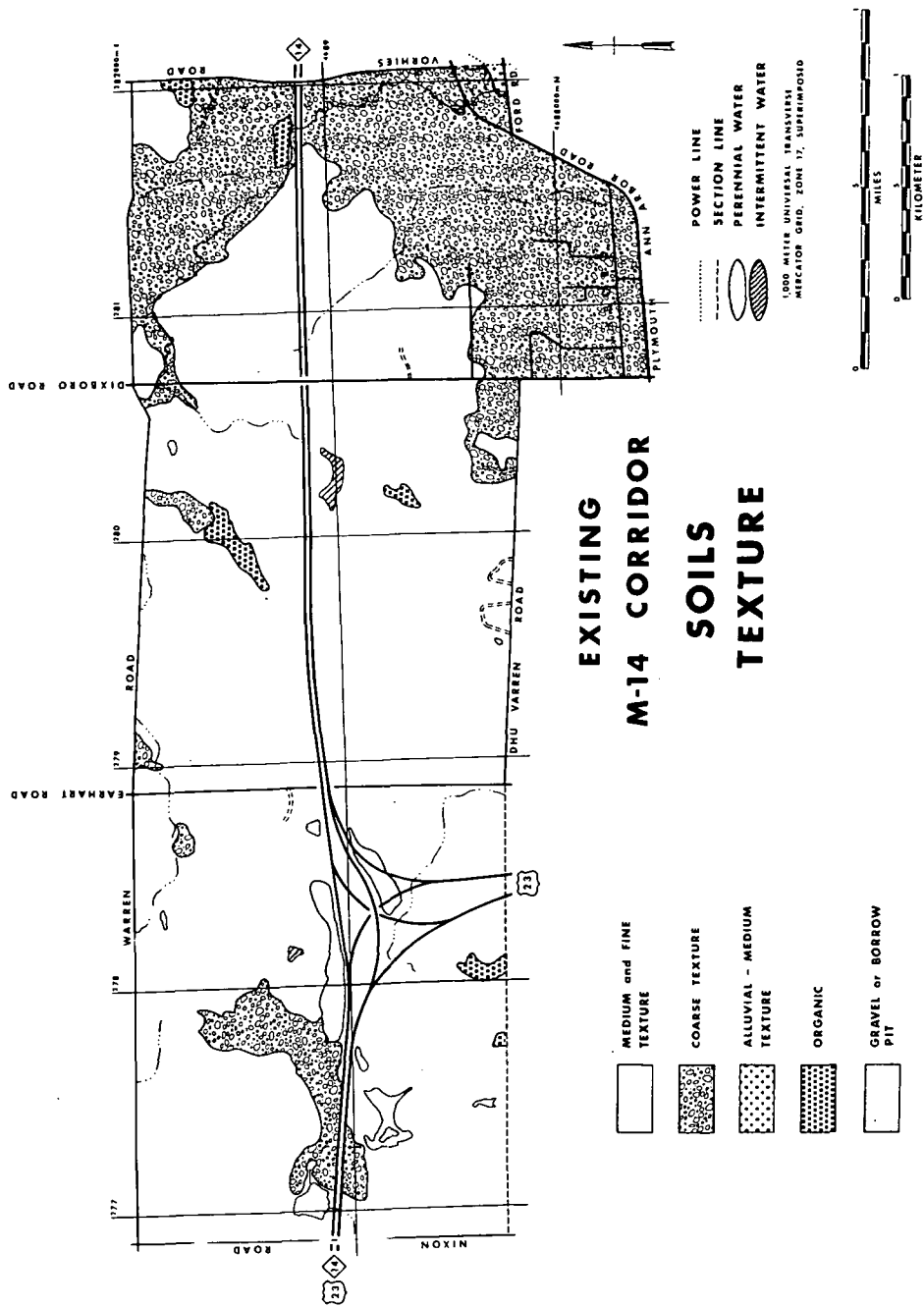


FIGURE 2. SOILS TEXTURE, SEGMENT I

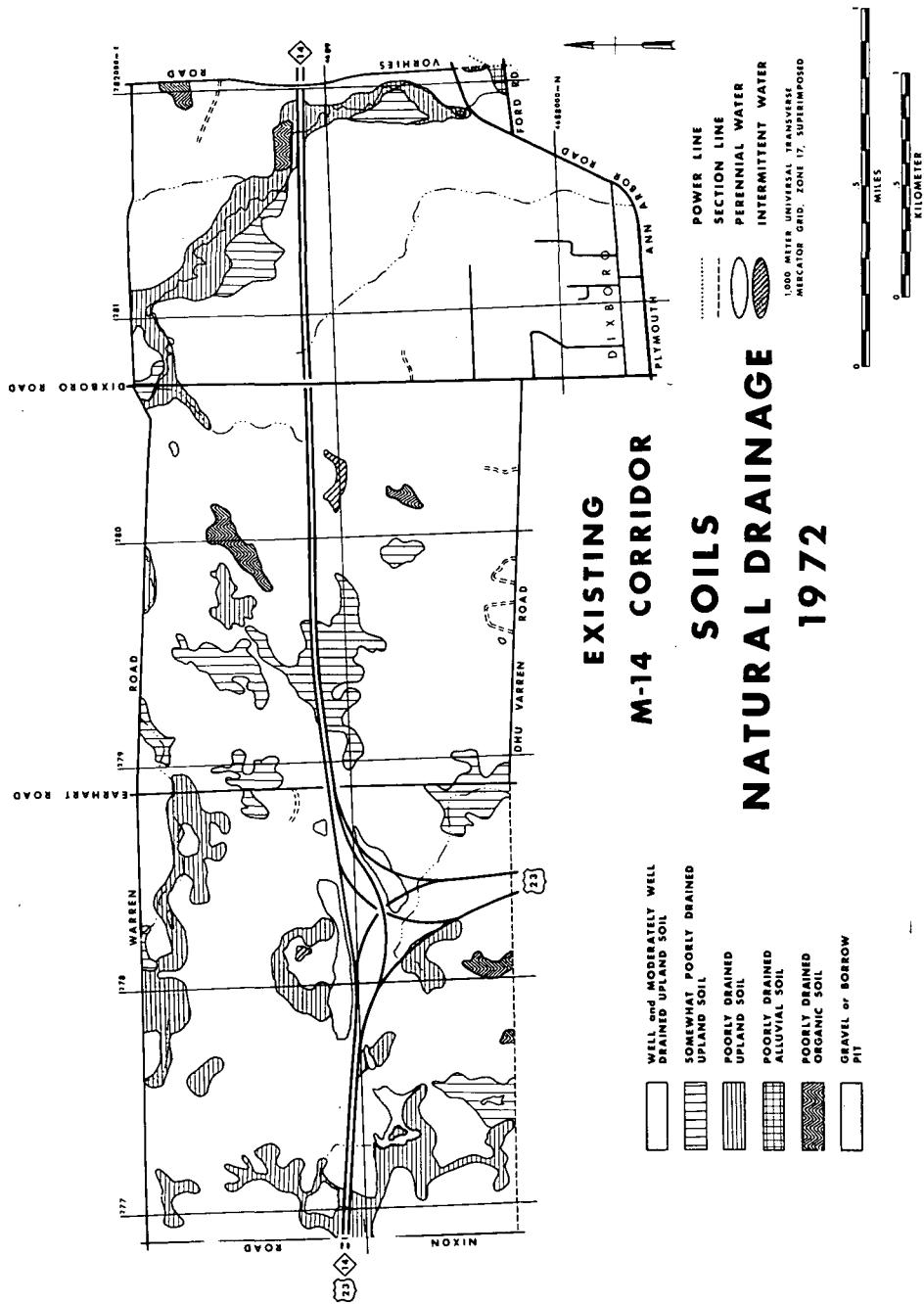


FIGURE 3. SOILS NATURAL DRAINAGE, SEGMENT I

and moderately well drained soils predominate in this area, considerable amounts of somewhat poorly drained and poorly drained soils are found in the proposed route of M-14 (Fig. 7). The landscape of Segment II is generally more rolling than that of the existing route. There are significant amounts of land with 12 to 40% slopes. However, the entire length of the proposed M-14 freeway in this area has been located on soils which have less than 6% slopes (Figs. 7 and 13).

In Segment III, the proposed route crosses two major areas of organic soils (Fig. 10). The natural drainage of these soils, of course, is poor. In fact, along this portion of the proposed route, somewhat poorly drained and poorly drained soils are more abundant than well drained soils (Fig. 11). As with the others, the proposed route will cross only 0-6% slopes in this segment of the study site (Figs. 12 and 13).

In the area south of the existing M-14 freeway, the surface waters generally flow to the south. North of the freeway the surface waters generally flow to the north into an intermittent stream which flows under the highway and into Fleming Creek a short distance south of the freeway. In Segment II, surface waters flow into Fleming Creek which parallels the proposed freeway at this point. The extension will be located north of the creek and will cause a portion of the creek to be relocated. The surface waters in the eastern portion of Segment III also flow into Fleming Creek. Here, the freeway will not parallel the creek, but will cross it.

7.1.3. ASSESSMENT OF CHANGES

To determine the impact made on adjoining soils and surface water hydrology by the existing M-14 freeway, aerial photographs taken in 1970 were compared with those taken in 1958 and in 1963 before construction. The changes in soils and the surface water system during the period appear very slight; apparently, the highway had little or no lasting visible effect on the soils and surface water resources in the existing M-14 corridor. Five borrow and gravel pits have resulted from the construction of this portion of M-14. In addition, vegetation covers some effects that the highway has had on the environment, especially erosion and deposition.

The channel of a creek just west of Vorhies Road was relocated to parallel M-14 for about 200 m. This relocation apparently did not significantly affect the soils or surface water hydrology.

7.1.4. PREDICTION OF IMPACT

Soil erosion will occur along the proposed M-14 route during construction when bare soil is exposed [12]. The amount of soil losses as a result of water erosion is commonly less in Michigan from the medium and fine textured soils than from the coarse textured soils [27]. Predicted soil losses within the proposed M-14 corridor were determined using the universal

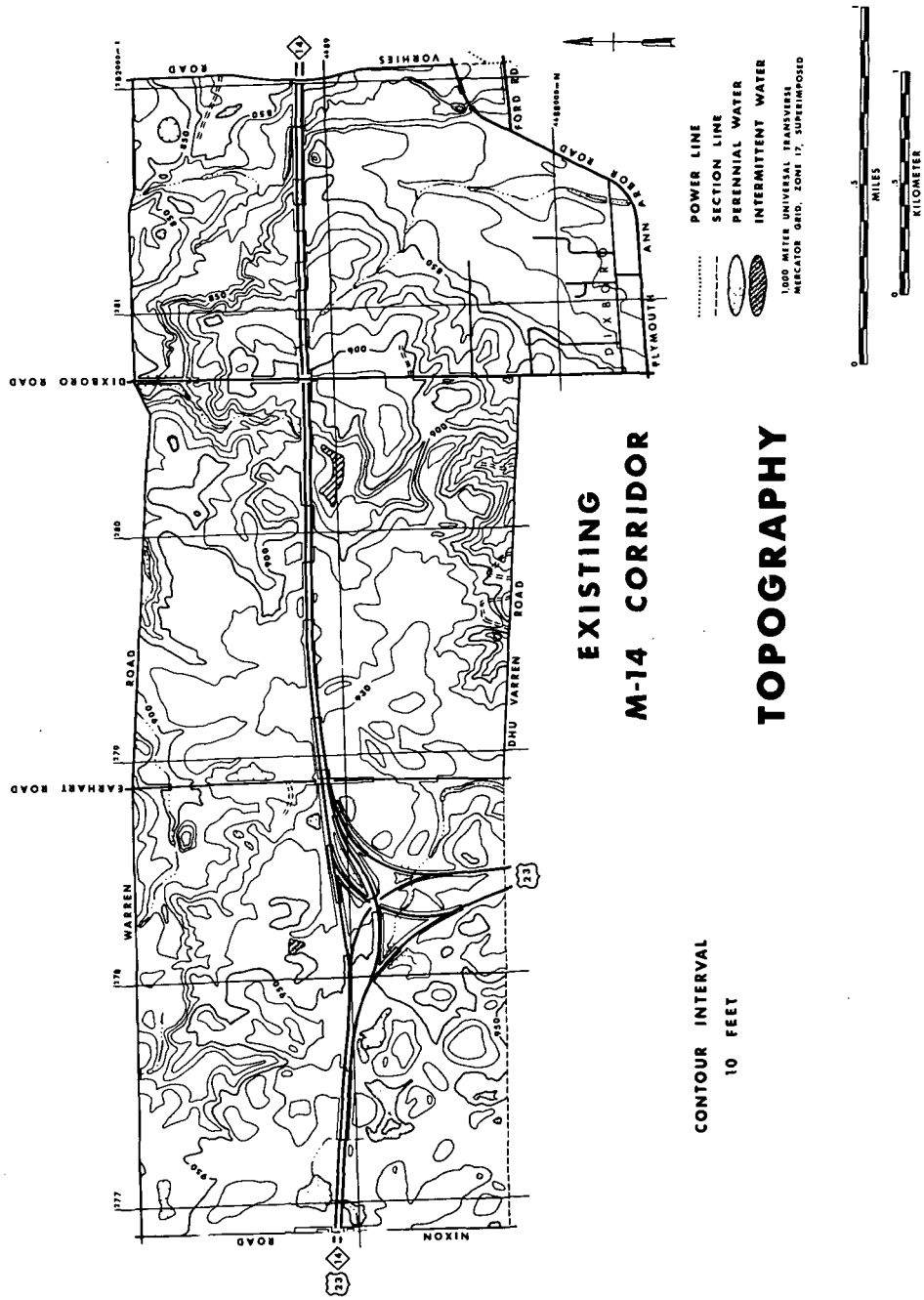


FIGURE 5. TOPOGRAPHY, SEGMENT I

PROPOSED M-14 CORRIDOR - WEST

SOILS -

TEXTURE

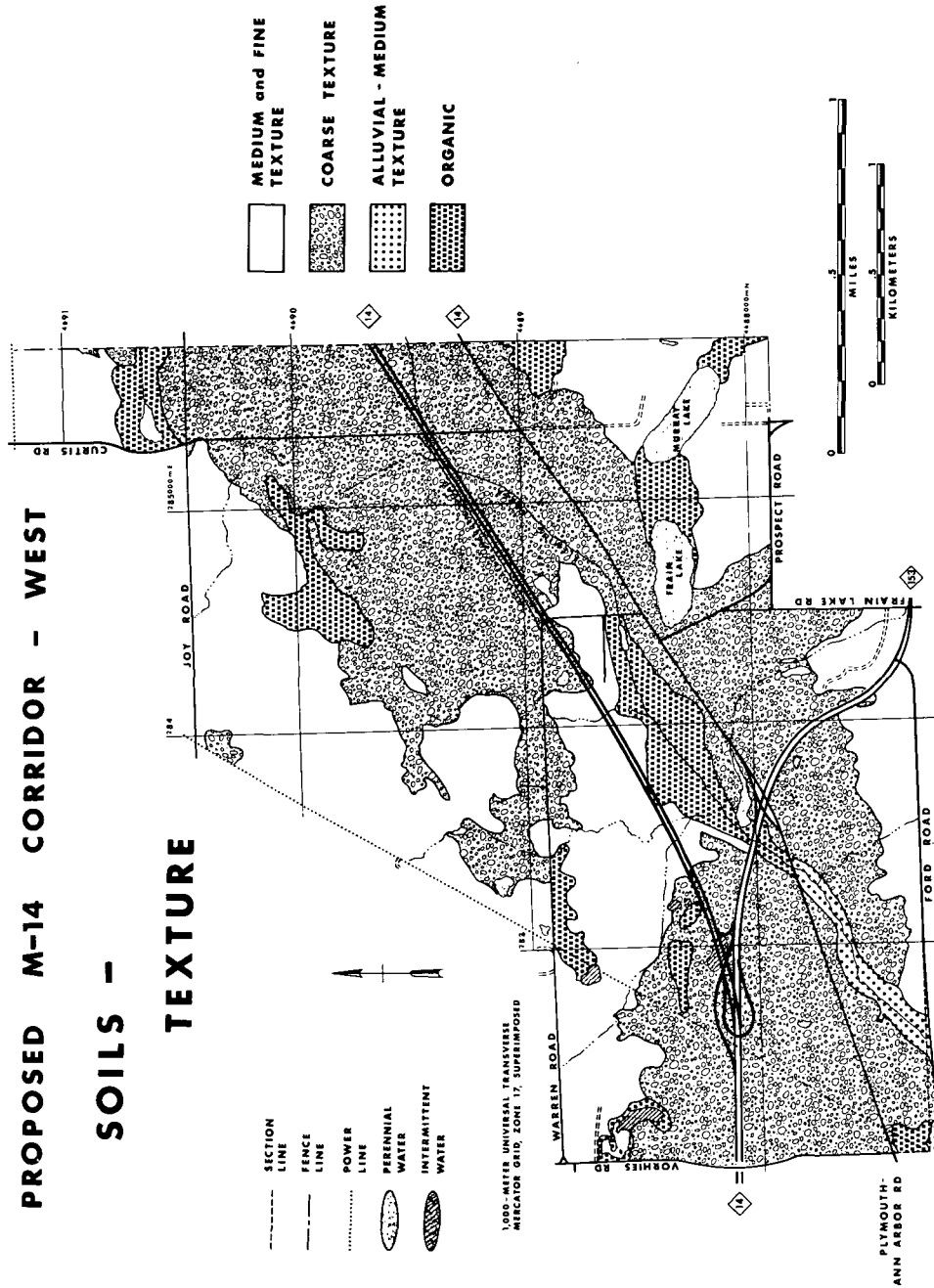
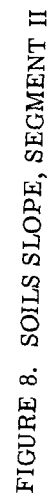


FIGURE 6. SOILS TEXTURE, SEGMENT II

1972



SOILS - SLOPE



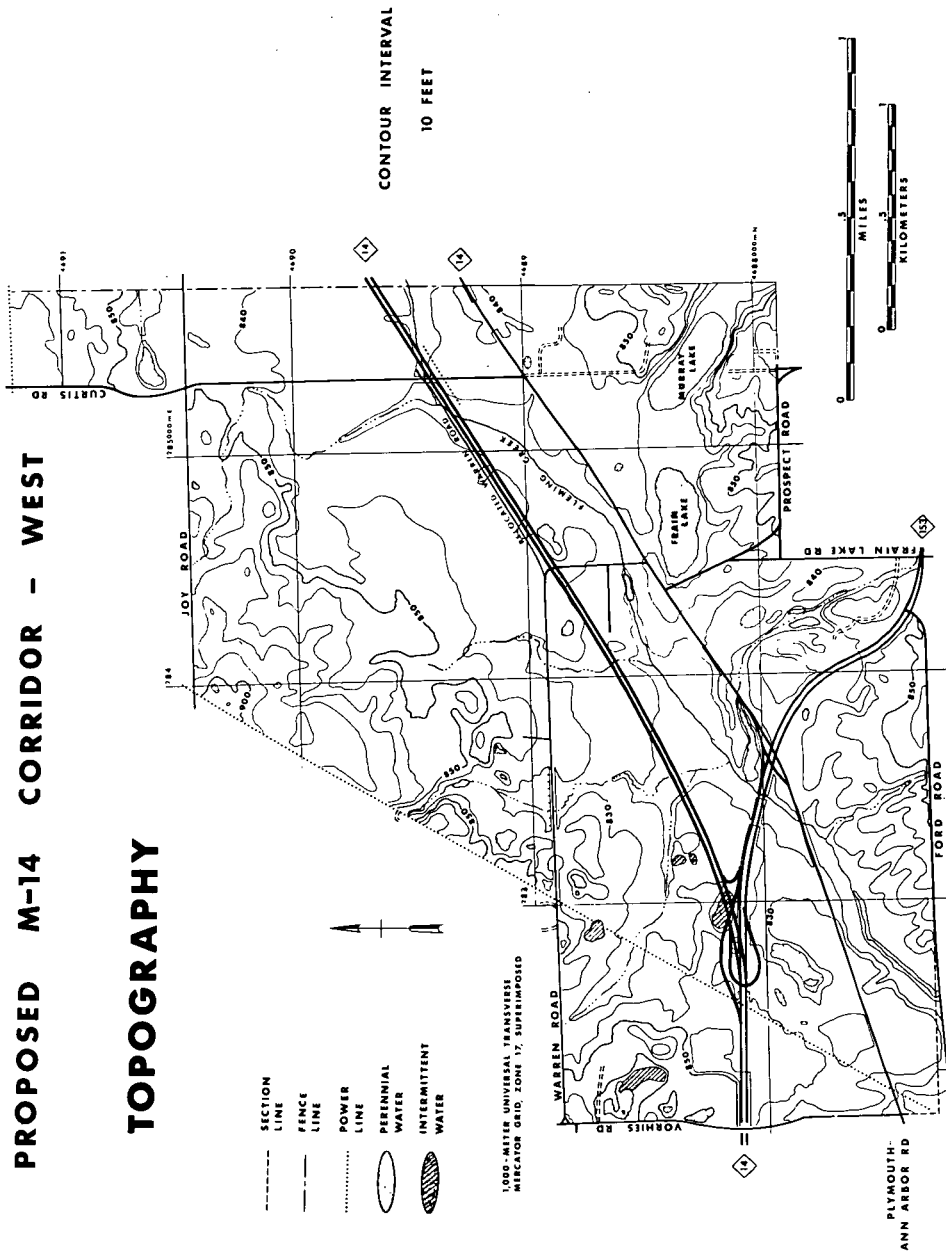


FIGURE 9. TOPOGRAPHY, SEGMENT II

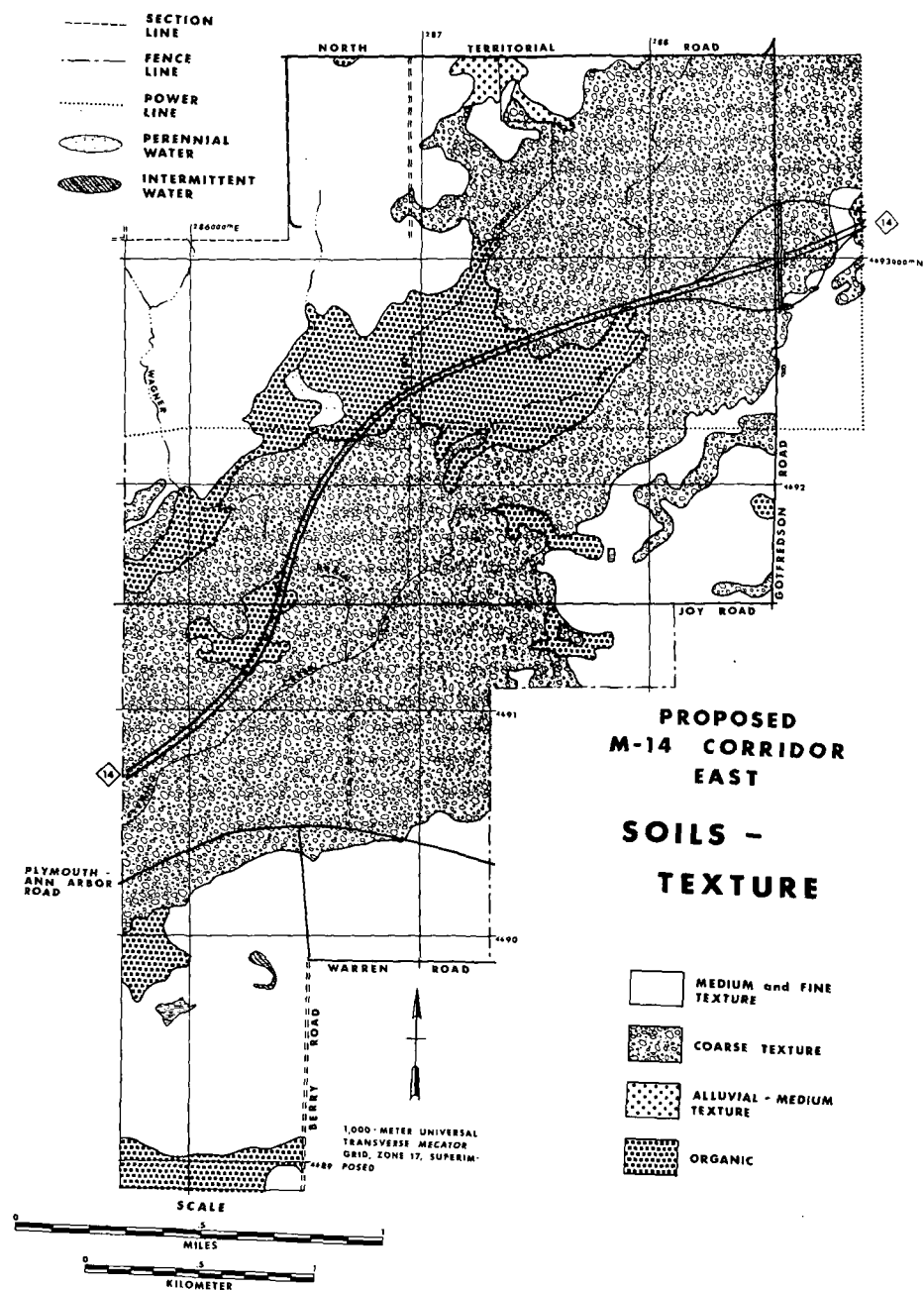


FIGURE 10. SOILS TEXTURE, SEGMENT III

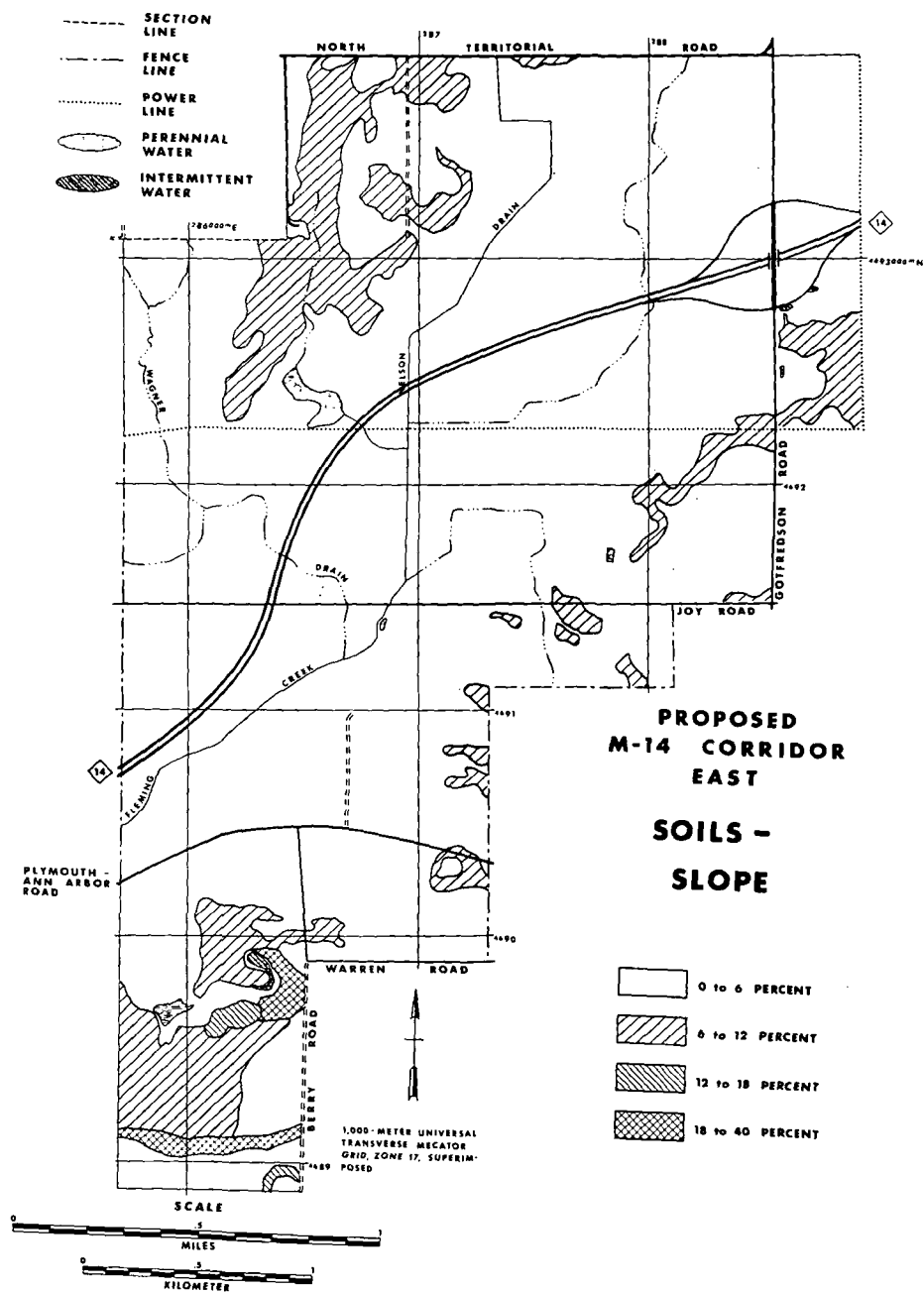


FIGURE 12. SOILS SLOPE, SEGMENT III

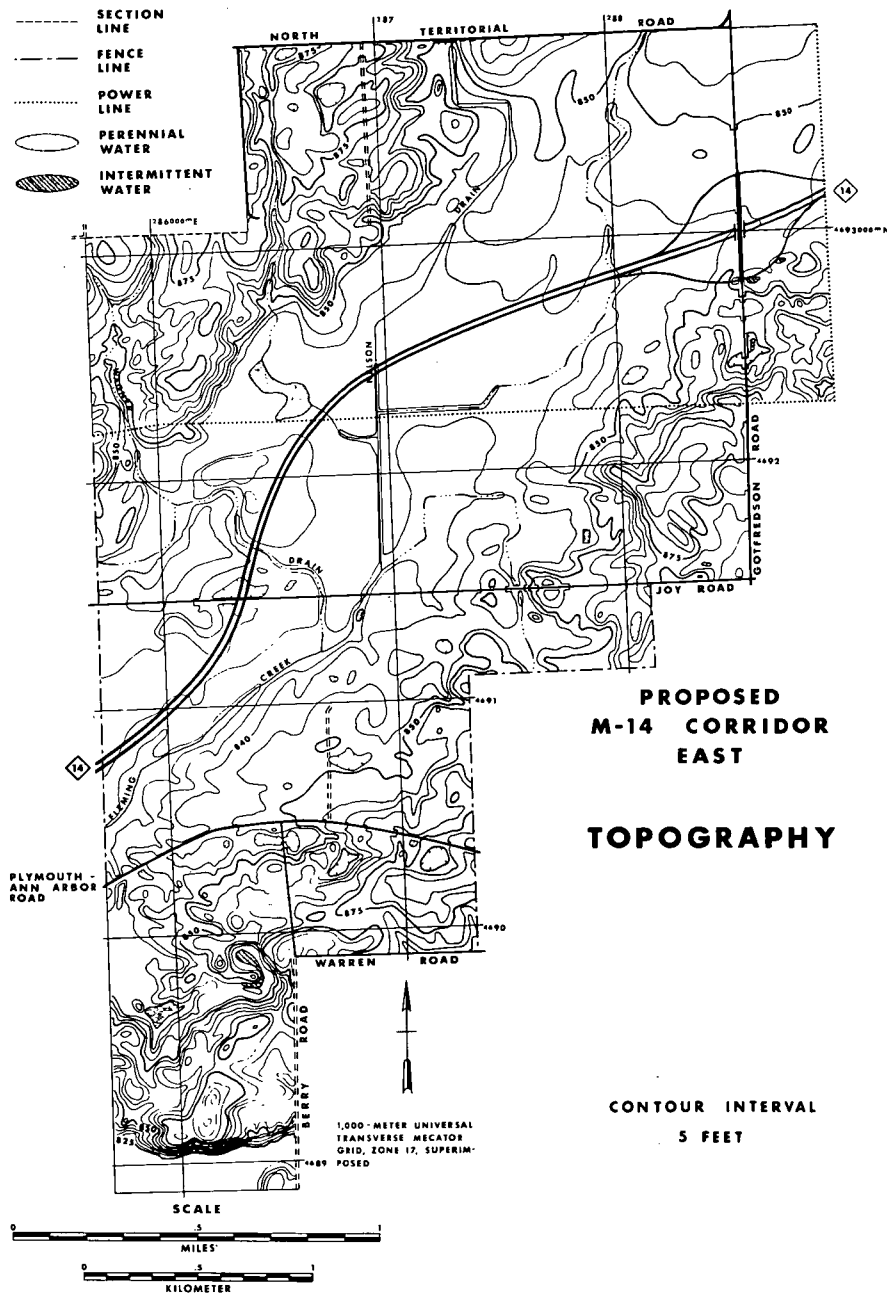


FIGURE 13. SOILS TOPOGRAPHY, SEGMENT III

soil erodibility nomograph [25, 26]. These soil losses are estimated for the A, B, and C horizons as they exist naturally (Table 1). During construction, horizons are commonly compacted, decreasing their permeability, and increasing their erodibility. Actual recorded losses of water and soil from erosion demonstration plots in Michigan indicate that water losses are greater and soil losses are less from the medium and fine textured soils [27].

As the slope of the soil surface increases, the predicted soil losses resulting from water erosion also increase (Table 1). The amount of eroded material entering Fleming Creek may be reduced by constructing sediment basins to allow the sediment to settle out of the runoff waters. Mulching and seeding or sodding exposed soil soon after the roadway is prepared will reduce erosion and subsequent sedimentation.

Borrow pits will be created by the excavation of materials needed for construction. Pits located in somewhat poorly drained and poorly drained soils will fill with water or will have some water in the pit for some portion of the year. The pits located in well drained soils may have water in them for a portion of the year or permanently, if they are dug below the level of the ground water.

Because the existing portion of M-14 does not traverse any large poorly drained areas, it is not possible to predict accurately from studies of this segment the impact that the proposed M-14 freeway will have on the soils of the large poorly drained area north of Joy Road between Curtis and Gottfredson Roads (Fig. 11). The ditches along the highway may become artificial drains and may lower the natural water table in the adjoining area. This artificial drainage may have a great impact on the vegetation of the area. The somewhat poorly drained and poorly drained, coarse textured soils and organic soils which will be traversed by the proposed M-14 freeway may be more susceptible to highway effects than the well drained medium and coarse textured soils along the existing M-14 freeway. A significant conclusion is that the highway can have a lesser environmental impact if it does not cross the large area of poorly drained mineral soils and organic soils.

The relocation of a portion of Fleming Creek may have a more significant effect on the environment than the relocation of the intermittent stream along the existing M-14 freeway. The larger volume of water which flows through Fleming Creek than that which flows through the intermittent stream may cause greater erosion of the new banks of Fleming Creek.

Soil losses resulting from wind erosion are also greater from coarse textured soils than from medium and fine textured soils [28]. Dry organic soils when bare are even more susceptible to wind erosion than mineral soils. Organic materials excavated from the roadway and piled along the highway will be especially susceptible to wind erosion after they dry.

TABLE 1. PREDICTED SOIL LOSSES FROM A, B, AND C HORIZONS OF SOILS
WITHIN THE FLEMING CREEK WATERSHED

Average Profile Texture	Horizon	% of Slope:**	Loss of Soil*			
			Metric Tons Per Hectare Per Year (Tons per acre per year)			
			0-6	6-12	12-18	18-35
Coarse	A		0-11.1 (0-25)	11.1-32.2 (25-72)	32.2-60.0 (72-135)	>60.0 (>135)
	B		0-14.3 (0-32)	12.0-38.8 (27-87)	33.4-75.0 (75-168)	>64.1 (>144)
	IIC		0-0.45 (0-1)	0.45-0.89 (1-2)	0.89-2.2 (2-5)	>2.2 (>5)
Medium and Fine	A		0-13.8 (0-31)	9.8-37.8 (22-85)	26.7-72.5 (60-163)	>51.2 (>115)
	B and C		0-13.4 (0-30)	13.4-39.6 (30-89)	39.6-74.4 (89-167)	>74.4 (>167)

*Soil losses were predicted using the universal erosion equation [25, 26].

**Predictions of soil loss are based on a 200 feet long slope.

7.2. VEGETATION ANALYSIS

The potential impacts of highway construction and maintenance on vegetative communities have already been discussed in Section 5. To summarize, three categories of potential impacts must be considered: (1) the direct destruction of vegetation by construction, and the longer range effects of this exposure on the residual vegetation; (2) the alteration of site conditions resulting from the presence of the highway and the manner in which it is constructed; and, (3) the long term effects of highway pollutants such as de-icing salts and exhaust emissions on the roadside vegetation. This section contains the results of impact assessments for vegetation at the M-14 site and the role of remote sensing in making the assessments.

7.2.1. VEGETATION CATEGORIES

As a basis for assessing the impact of highway construction on the vegetative resources of an area, vegetative cover can be divided into four general categories based on the successional stage of the vegetative community. At least three major considerations for utility planning and impact assessment increase with successional stage. First are changes that can be expected to result from disturbance of the vegetation. Second, in regions with a forest climax, the physical size of the individual plants generally increases with successional stage, thus increasing the cost of clearing and properly disposing of cleared materials. Third, the time required to restore the vegetation to its present state after temporary clearing also increases with successional stage. The ranking of map categories with increasing successional stage is

- (1) annuals or bare
- (2) herbaceous perennials
- (3) brushland and mixed types
- (4) forest

However, some anomalies can occur in the mixed types category.

Annuals or bare—Areas in which perennial vegetation covers less than 50% of the surface except areas with more than 10% shrubby or arborescent cover. This class is assumed to include areas subjected to clearing, building, or hand surfacing by man.

Herbaceous perennials—Areas in which the ground surface is 50% or more covered by herbaceous perennial vegetation during the growing season, while not exceeding 10% shrubby and arborescent cover. This type encompasses grassland, grass/forb (other small herbaceous plants), and swamp grass vegetative communities.

Brushland and mixed types—Areas in which the combinations of vegetation do not meet the specifications for the other three categories. The cover includes more than 10% trees and shrubs, but less than 50% trees.

Forest—Areas in which the ground surface is 50% or more covered by vertical projections of tree crowns. For purposes of this classification, an individual plant must be at least 5 m in height to be considered a tree.

A map based on these four categories can be prepared from any relatively recent aerial photography with a minimum amount of ground truth. As the scale of the photography decreases or the age increases, the amount of ground truth needed also increases. Color is an aid to interpretation, especially with small scale photos of the type used in this study. Interpreters can work productively with a minimum of training. The most difficult separation for the interpreter to make is between herbaceous perennials and annuals. Cultivation patterns and color are the most helpful clues for making this separation.

The best format for this kind of map is a transparent overlay. Such an overlay is interpretable at a glance, and can be superimposed on other maps to study the interaction of vegetation with cultural and other natural resources. If the overlay format is not used, it might be desirable to add an additional category for water, one for built up areas, and one for the impervious surfaces. Since this kind of map is designed to provide generalized rather than detailed information, a minimum type size of two hectares (five acres) is adequate.

7.2.2. VEGETATIVE CHARACTERISTICS OF THE AREA

The M-14 Test Site as a whole is a rural, agricultural area that lies mostly within the Fleming Creek Watershed. This creek empties into the Huron River just south of the study site. The site includes both uplands and lowlands. The distribution of vegetation in the area has been controlled by the interaction of moisture conditions and the area's history of agricultural land use. Woodlands are limited for the most part to poorly drained areas that are too wet for cultivation, while the sites with better drainage are devoted to row crops and grasses.

A generalized vegetation map with four categories was prepared for each of the three study segments (Figs. 14, 15, 16). Table 2 provides a summary of the vegetative cover by segment in terms of the same categories that are used on the maps. The percentages in this table do not quite total to 100 because water and roadways have been omitted from the tabulation. On the whole, approximately 20% of the area consists of annuals (small grains and row crops) or unvegetated areas, 40% grasses, 20% brushland and mixed types, and 10% woodland.

The species composition of the woodlands in the area varies according to the moisture characteristics of the site. Oak/hickory stands occupy the sites with better drainage. The more moist sites primarily contain maples, although maples also constitute a significant component on the drier sites as well. Cottonwoods and willows are prominent in the wet areas. A diverse mixture of minor species is typical of all woodlots in this area. With a few exceptions, the

PROPOSED M-14 CORRIDOR - WEST

VEGETATION

1972

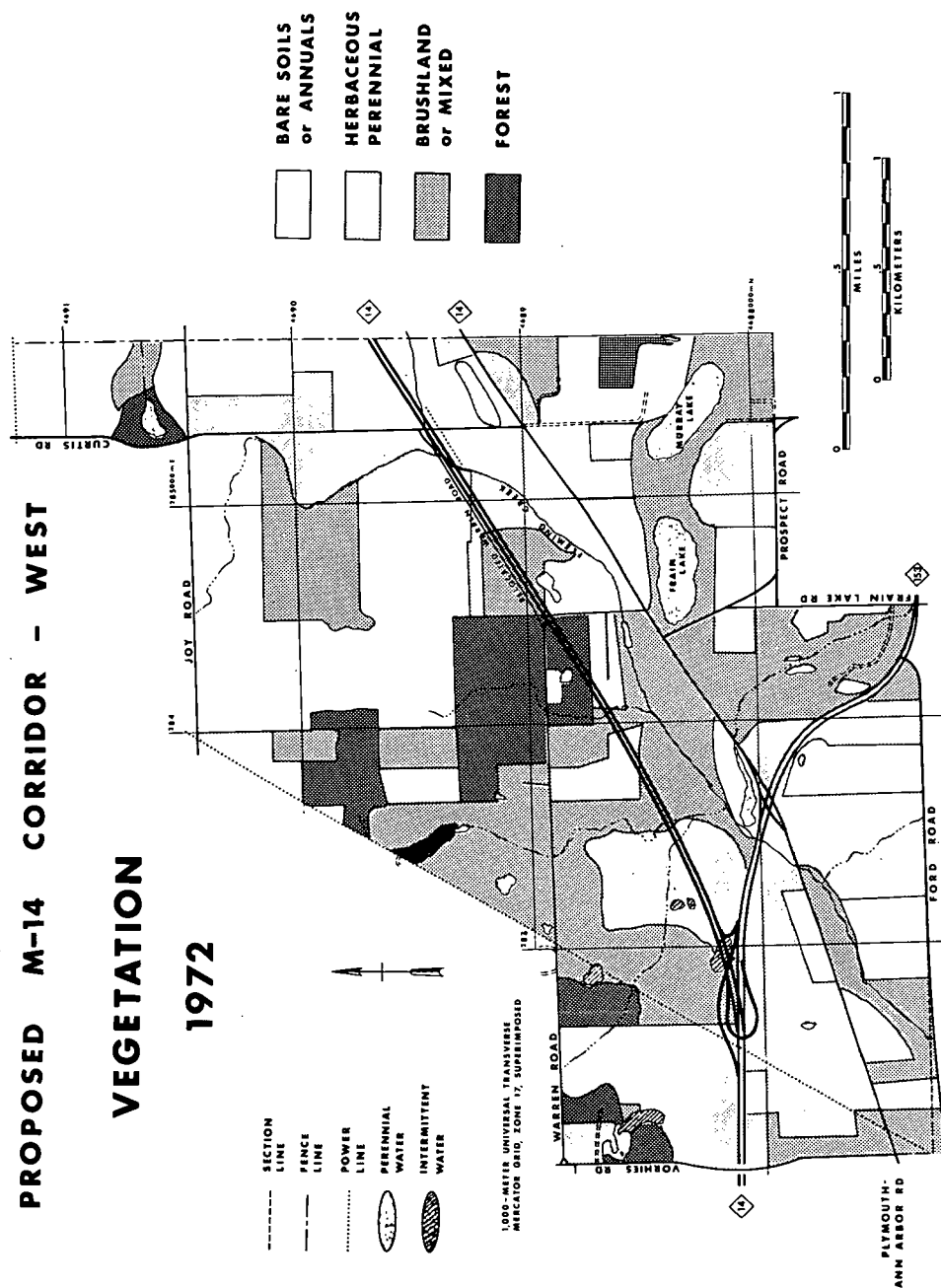


FIGURE 15. VEGETATION, SEGMENT II

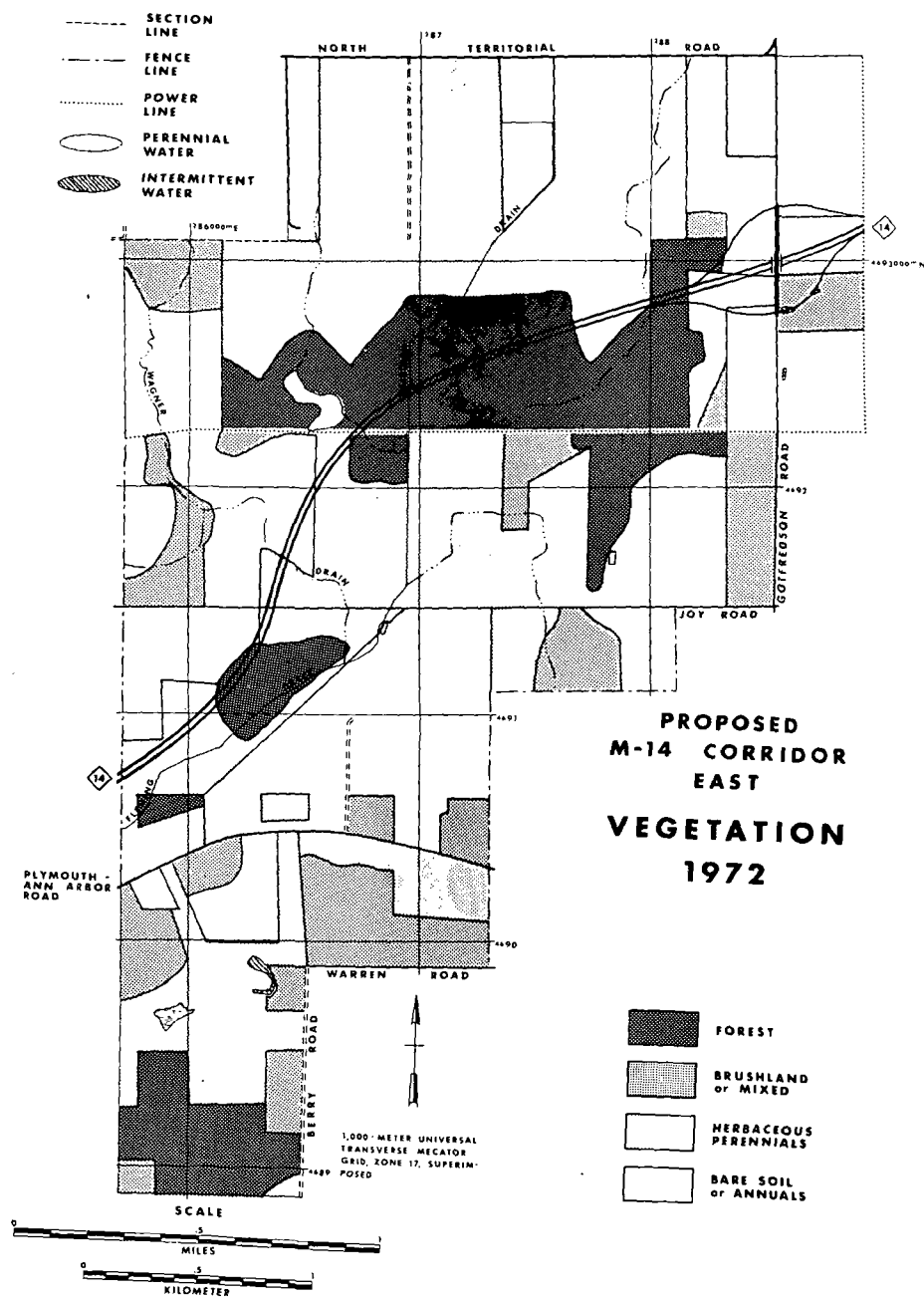


FIGURE 16. VEGETATION, SEGMENT III

woodlots in the area are, or could be, managed for farm forestry. However, several of these woodlots are presently young and/or understocked. The primary values of these woodlots fall in three categories:

- (1) Much of the area in wet woodland is maintained as private game preserve.
- (2) The drier woodlands in the southern portion of the area are being used as residential construction sites, presumably because of the park-like atmosphere offered by the woods.
- (3) The woodlands constitute one of the main aesthetic features of the rolling terrain.

Information on species composition of the plant communities is not recorded in the four-way vegetation map. Furthermore, this kind of information is very difficult to extract from the small scale photos used in this study. Photointerpretation of species composition requires scales no smaller than 1:40,000. Even then, ground checking is necessary. In this study, detailed information on species composition and stocking was obtained through a combined photo and ground survey in which classifications were made by one-hectare cells. The information gathered is being used to develop an information storage/retrieval/presentation system for inventories of terrain characteristics. From these efforts, it has become apparent that one-hectare units are not economically feasible for impact assessments. However, an optimum cell size has not yet been determined.

7.2.3. ASSESSMENT OF CHANGES

The design of the existing portion of the M-14 freeway in Segment I has engendered little change in the vegetational communities that could be detected by the methods of assessment used in this study. The highway passes along the edges of the wet woodlands on relatively high ground, thus taking advantage of the screen effects of the woodlots without actually passing through them. The one exception occurs at the interchange with US-23. Interchanges may constitute serious barriers to natural drainage. Proper design of the ditches is important. If the ditches are too shallow, they can cause flooding during periods of high water; if they are too deep, they can result in swamp drainage during drier periods. The highway passes directly through a wet woodland just west of the interchange with US-23, and high water has remained in this area long enough to cause some mortality of trees.

There is a general trend throughout the area of previously cultivated land reverting to grass and brush. This shift is documented by a vegetation change analysis prepared by comparison of older with more recent photos (Table 3). The presence of the highway and plans for extension have probably contributed to this trend as land speculators acquire agricultural land and hold it idle for future development. However, the primary cause of this shift appears to be the changing economics of agriculture. Cessation of cultivation will permit the land to develop

TABLE 2. SUMMARY OF VEGETATIVE COVER

Segment	Annuals or Unvegetated (%)	Herbaceous Perennials (%)	Brushland and Mixed (%)	Forest (%)
I	7.1	47.7	34.1	11.1
II	26.4	32.0	31.2	8.8
III	25.2	43.3	16.2	14.9
Average	19.6	41.0	27.2	11.6

TABLE 3. VEGETATION CHANGE, 1963-1972

	Segment I	Segment II	Segment III	Total
Crop to Grass				
Hectares	467	182	Not	649
(%)	39.0	14.7	Analyzed	27.6
Forest to Grass				
Hectares	40	0	Not	40
(%)	1.9	0	Analyzed	1.0

permanent cover and thus improve the environmental quality of the area. If areas held by speculators are subsequently developed for commercial purposes, the disturbance in the natural environment associated with these activities will likely be much more extensive than the direct impact of the highway.

7.2.4. PREDICTION OF IMPACT

In Segment II the proposed interchange with M-153 poses the greatest potential for changing the ecology of the area. The proposed location for this interchange is wet with diffuse drainage. The interchange will act as a barrier to natural drainage, but its actual impact will depend on the nature of the ditches. If the ditches are shallow, the low areas will be flooded during periods of high water. Conversely, ditching below the natural water table will result in permanent drainage of the swamp. If the ditches are constructed so as to maintain the natural water level, impacts beyond the right-of-way may be reduced to occasional plant mortality during periods of high water. However, construction of the highway in Segment II should cause little change in vegetation outside the area just mentioned.

The proposed location of the highway in Segment III runs directly through the largest forested wetland in the vicinity. This area contains yellow birch (Betula alleghaniensis) which is relatively rare in this region. Portions of this area are also maintained as private game preserve.

An obvious consequence of the construction through this area is the destruction of timber and wildlife cover on the right-of-way. Potentially more serious, however, are changes in drainage. Effects of construction on drainage could range from periodic flooding with shallow ditches to lowering of the natural water table with deep ditches. In either case, the character of the forest vegetation would change through mortality and shifts in patterns of reproduction. Furthermore, the seepage of saline water from de-icing salts along the highway can be expected to cause considerable plant stress in a swampy area of this type. Since border habitat is already provided by a power line right-of-way, the removal of vegetation and disturbance from construction and traffic on the highway will operate to the detriment of resident wildlife.

In addition to the impact on the forested wetland, the interchange with Gottfredson Road on the proposed route involves extensive removal of organic deposits. Since muck sites support distinctive flora and fauna, the removal of these deposits will involve major ecological changes as well as higher construction costs.

In short, the ecological impacts in Segment III would be much less extensive if the proposed route were moved slightly south to better drained soils.

7.3. LAND USE ANALYSIS

As mentioned in Section 5, land use changes in an area are the result of many interrelated forces, particularly economic and social forces. The task of assessing the economic and social impact of a new highway installation requires the use of analytical methods of isolating those factors which are the direct or indirect result of the existence of the highway. The natural resources and their changes have already been discussed. The work reported in this section illustrates methods which can be used for a limited number of aspects of social and economic impact assessment.

It is important to note that the test site area extends only 1 km on either side of the highway centerline. Although a corridor of this width appears to provide ample room to examine ecological impacts, the effects on land use should be studied over a much larger area. However, the 2 km strip was adequate to illustrate methods of using remote sensing and other techniques in observing and measuring changes in land use.

Because of these limitations, the study was designed to reach only tentative conclusions on cause-effect relationships between highway construction and changes in land use. This portion of the study, however, provides the outlines of a methodology which can be further refined for effective preparation and presentation of land use analysis.

The section begins with a set of definitions of land use classes and a brief description of the historical development and current conditions within the area, providing information needed to understand the nature and extent of changes likely to occur in the future. Within the limitations mentioned above, land use in the M-14 area is then analyzed for two purposes:

- (1) Sequential aerial photography is used to measure the changes in land use occurring between 1963, before the M-14 freeway was constructed, and its current condition in 1972. The extent of changes in Segment I is compared to the changes in Segments II and III, to provide a rough indication of the differences in area development which might be directly attributable to the installation of the highway in Segment I.
- (2) The current land use patterns in Segments II and III are studied to estimate both direct and indirect future impact of the highway construction in these areas.

7.3.1. LAND USE CLASSIFICATION SYSTEM

A specific land use classification system was devised for this study and is defined in this section. This system was derived principally from that developed by the Land Use and Natural Resources Program (LUNR) at Cornell University [29]. However, the rural character of the M-14 study area necessitated the elimination or modification of many categories included in the Cornell study. Some definitions were combined for convenience, but can be reintroduced

should future land use changes warrant it. The categories selected for certain land uses are not necessarily coincident with those used for the thematic studies of vegetation discussed in Section 7.2.

Definition of land use classes is as follows:

Agricultural land (FA) has been identified by well maintained brush free fields, row crops, or furrow marks in the soil. Included in this category are orchards, vineyards, horticulture/floriculture, cropland intensively used for cash crops, land used more extensively for crops in general farming and for dairy and poultry operations, pasture, and specialty farms.

Open space (O) has been divided into four categories distinguished by their cover type and apparent major use:

Idle land (OI) refers to land neither in agriculture nor forest, and for the purposes of this study includes land in highway right-of-way. For our study, these areas range from partial brush cover (land abandoned for 3 to 5 years) to heavy brush cover (less than 50% tree crown cover).

Forested land (OF) has a tree crown cover of at least 50% and an average tree height of at least 10 m (30 ft).

Recreational land (OR) includes all outdoor recreation (golf courses, parks, swimming facilities, and school playgrounds). While extensive areas of private and public lands and waters are used for outdoor recreation such as hunting, fishing, hiking, and sight-seeing, the types of recreational land mapped as OR are those for which specific activities have been developed to an intensity level constituting the predominant use of the land.

Cemetery land (OC) is comprised of those areas currently in use as, or planned for, a cemetery, memorial garden, and the like.

Commercial areas (C) are those whose activities are predominantly connected with the sale of products and services. These are represented by a point symbol.

Extractive industries (IE) are the only industrial land use within the study area. Both borrow and gravel pits are included in this category. These extractive areas were included with idle land when probable abandonment was indicated by the presence of grass and brush.

Residential land (R) is separated into three types:

Single housing units (RS) occur primarily in strip development along roadways. These include rural nonfarm and rural farm housing units. Housing units in this category occur in groupings of five or fewer per 300 m of roadway frontage. For this study, they have been identified on the maps by a point symbol.

Light residential areas (RL) have a density of fewer than five housing units per hectare and occur in units of 2 hectares or more. These may appear in strip development adjacent to roads.

Medium residential area (RM) is characterized by a density of five or more housing units per hectare and occurs in units of 8 hectares or more. These do not appear as strip development along major roadways.

Institutional land (I) consists of both educational (point symbol) and church uses (point symbol). The educational areas include the entire area of buildings and parking. The church areas include the structures and grounds devoted to religious use, but do not include facilities for associated church schools or cemeteries.

7.3.2. HISTORICAL DEVELOPMENT AND DESCRIPTION OF THE AREA

The M-14 Test Site is not an isolated area, but part of a larger region including the cities of Ann Arbor, Plymouth and Ypsilanti. Thus, the study site falls under the influence of those factors affecting development and changes in these cities and much of Southeastern Michigan as well.

In the 1800's, this region was settled in small farming communities, and remained predominantly agricultural until the early part of the 20th century. World War I spurred the local economy with an emphasis on agricultural production; World War II brought increased industrial activity to the area. The construction in the 1940's of the Willow Run aircraft facilities brought an increased immigration of job seekers. The residential development which followed, however, occurred southeast of Ypsilanti, and left the study site in agricultural use.

Substantial growth of Ann Arbor after World War II resulted from the rapid expansion of The University of Michigan and the development of research-based industry. The resulting increase in population brought pressure to bear on existing transportation systems. To alleviate this pressure, I-94 was constructed from Detroit through Ypsilanti and Ann Arbor to Chicago. This acted to further isolate the study site, as no major road network connected with it.

Two events of the late 1950's and early 1960's had an effect upon the study area. The first was the construction of US-23 connecting Flint with Toledo. This link, circling Ann Arbor on the east, provided secondary access to the study site from the south. Now, access to the study site from Ann Arbor was assured. However, because of the fringe location of the site, few changes in land use occurred which included only a slight increase in residential construction.

The second event was the industrial growth of Plymouth. The effect on the study site from this event was not immediate, but it did mark the expansion of the Detroit metropolis to the eastern edges of the study site. Thus, the existing highway links between Ann Arbor and Plymouth

and in fact western Washtenaw County and Detroit were soon congested and inadequate. I-94 to the south and I-96 to the north began to show the pressure of heavy use. These factors initiated the action to improve the highway between Ann Arbor and Plymouth.

In 1964, construction was started on the M-14 freeway, with the first 5 km opened in the same year. This 4-lane section joins US-23 on the west and terminates at Ford Road on the east. M-14 presently continues along Plymouth-Ann Arbor Road, a 2-lane highway. Plymouth-Ann Arbor Road and Ford Road provide the only local access to the 4-lane section of M-14 freeway.

Local traffic flow will increase substantially when the M-14 freeway link between Ann Arbor and Plymouth is completed. Daily average traffic volume is expected to increase from the present 7,500 to 47,000 in 1990 [23]. Although the rate and extent of land use change occurring in the study area has been small, one may predict that the number of changes in use will accelerate with the completion of the highway.

The use of land in the three segments of the study site in 1972 is shown in Figs. 17, 18, and 19. The impact of highway construction, however, must be assessed by study of changes in land use which occur over time. These changes, identified for the period 1963 to 1972, are represented in Tables 4 and 5.

7.3.3. ANALYSIS OF LAND USE CHANGES

There are a number of changes which can generally be expected to occur when a highway is built through a rural area near an expanding urban center like Ann Arbor. Four types of change have been examined: (1) a lessening of agricultural activity, (2) an increase in the number of dwelling units, (3) an increase in commercial activity, and, (4) industrial development. Remote sensing was used to identify and measure the magnitude of these changes in the test site from 1963 to 1972.

7.3.3.1. Decrease in Agricultural Activity

In 1963 agriculture was the predominant land use in the study area, both in total area and number of land parcels. Today, the area in agricultural land is second to the area in an idle state. However, agriculture remains as the primary income producing activity, not only in the study area, but also in Washtenaw County as a whole. Agriculture in the study site is found mostly in small, privately owned farms.

Row crop and small grains production is the chief activity in the area, although some small orchards are present. A significant number of these orchards appear abandoned, or in poor maintenance indicating a reduction in importance to the owner.

TABLE 4. LAND USES IN 1963 AND 1972

	Segment I		Segment II		Segment III		Total	
	1972	1963	1972	1963	1972	1963	1972	1963
Agriculture								
Hectares	333	486	517	612	734	868	1584	1966
%*	27.9	40.8	41.8	49.6	52.1	61.7	41.3	51.2
Recreation								
Hectares	4	4	5	5	43	43	52	52
%	0.3	0.3	0.4	0.4	3.1	3.1	1.3	1.3
Forest								
Hectares	143	144	109	117	161	161	413	422
%	12.0	12.1	8.9	9.4	11.5	11.5	10.8	11.1
Idle								
Hectares	660	515	553	474	469	335	1682	1324
%	55.5	43.2	44.7	38.3	33.3	23.7	43.8	34.5
Extracting								
Hectares	4	1	10	4	0	0	14	5
%	0.3	0.1	0.8	0.3	0	0	0.4	0.1
Cemetery								
Hectares	0	0	14	10	0	0	14	10
%	0	0	1.1	0.8	0	0	0.4	0.3
Light Residential								
Hectares	17	11	29	15	0	0	46	26
%	1.4	0.9	2.3	1.2	0	0	1.2	0.7
Medium Residential								
Hectares	31	31	0	0	0	0	31	31
%	2.6	2.6	0	0	0	0	0.8	0.8
Total Hectares	1192		1237		1407		3836	
	100%		100%		100%		100%	

* Percentages indicate fraction of total segment in each use.

TABLE 5. NET CHANGES IN LAND USE FROM 1963 TO 1972

	Segment I	Segment II	Segment III	Total
Agriculture				
Hectares	-153	-96	-134	-383
% Change	-31.5%	-15.6%	-15.4%	-19.4%
Recreation				
Hectares	0	0	0	0
% Change	0	0	0	0
Forest				
Hectares	-1	-7	0	-8
% Change	-0.6%	-6.3%	0	+1.9%
Idle				
Hectares	+146	+79	+134	+359
% Change	+28.3%	+16.7%	+39.9%	+27.1%
Extracting				
Hectares	+2	+7	0	+9
% Change	+200%	+177%	0	+183%
Cemetery				
Hectares	0	+4	0	+4
% Change	0	+36%	0	+36%
Light Residential				
Hectares	+6	+14	0	+20
% Change	+50%	+91.9%	0	+73.8%
Medium Residential				
Hectares	0	0	0	0
% Change	0	0	0	0

"% Change" is net change as percent of total hectares in each use in 1963.

PROPOSED M-14 CORRIDOR - WEST

LAND USE

1972

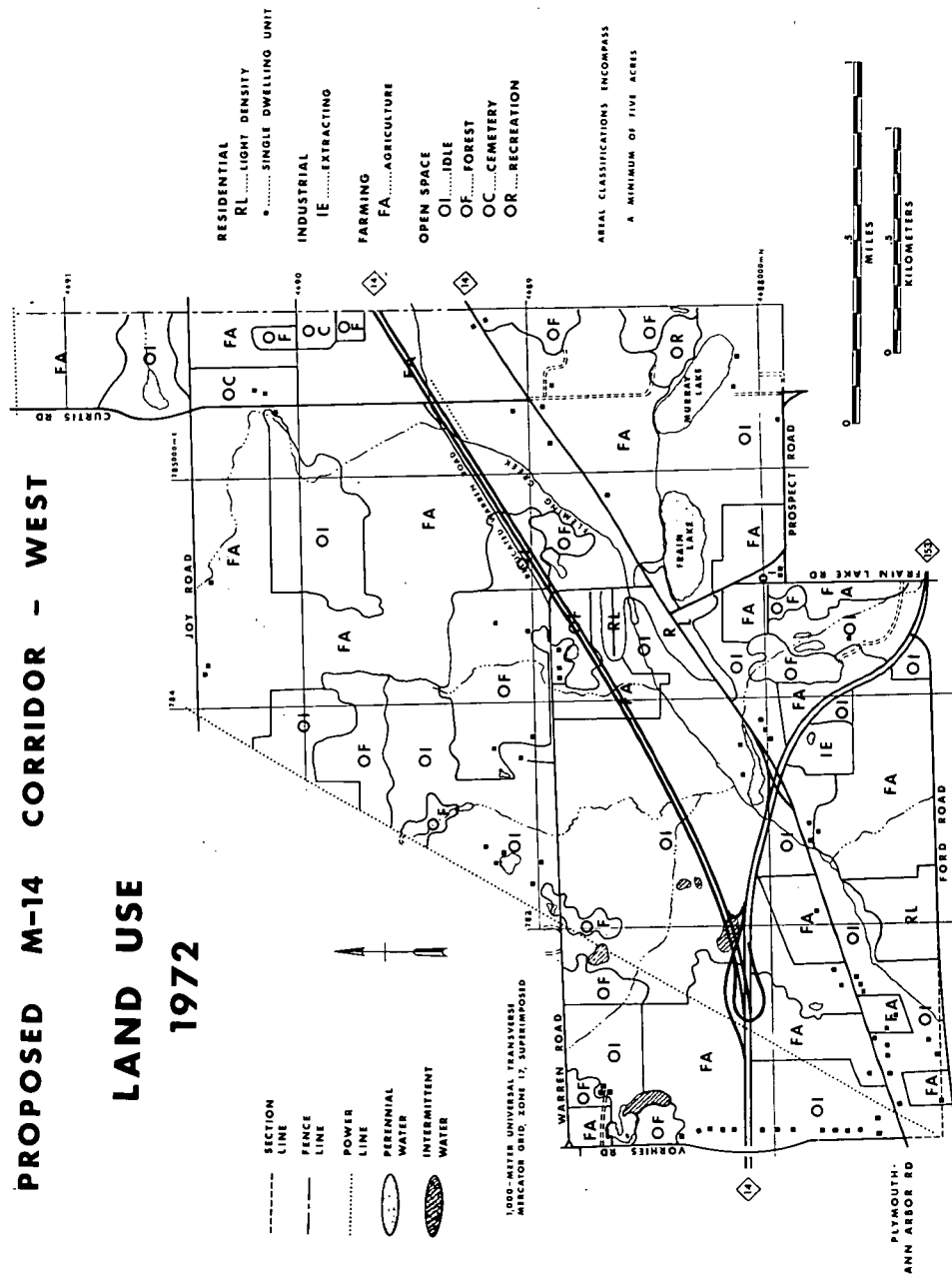


FIGURE 18. LAND USE, SEGMENT II

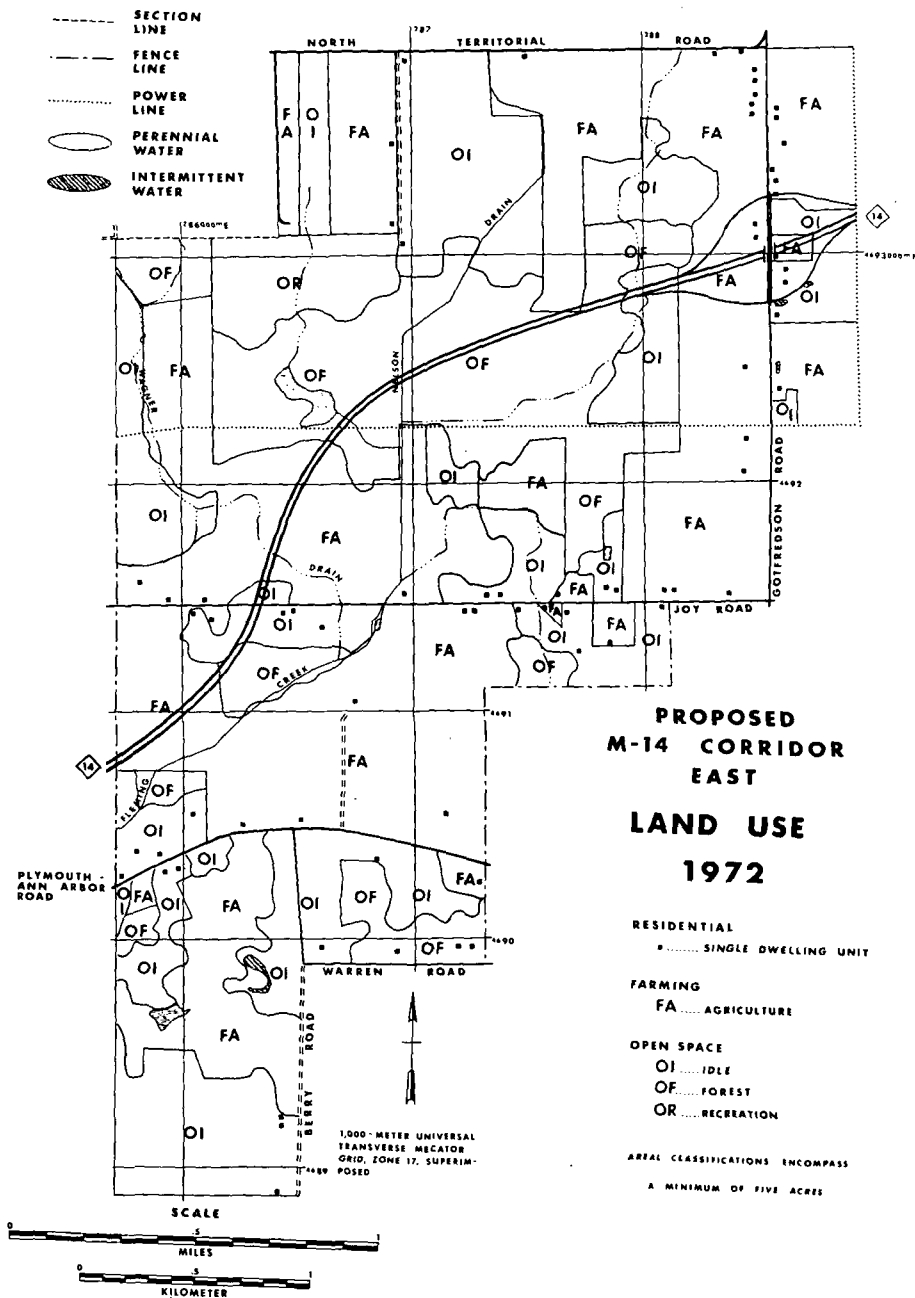


FIGURE 19. LAND USE, SEGMENT III

In other areas, the agricultural product is livestock, and the land is covered with grass for grazing and for hay. Knowledgeable observers of the area point out that an increasing number of farms are moving to livestock from more intensive agriculture. Dairy and horse farms dominate livestock production in the test area.

In general, there is ample evidence of a decline in the importance of agriculture in the study area. During the period from 1963 to 1972, one fifth of the land in agriculture (430 hectares) changed from agricultural to idle, extractive, or residential land use. Ninety-five percent of this shift was from agriculture to idle land.

As one might expect, the rate of change from agriculture to other uses was greatest in that segment of the study site where M-14 was constructed in 1964. In that segment, more than one-third of all agriculturally used land shifted to another use. In Segment III where very little development has occurred in the last decade, only one-sixth of land area in agriculture changed to another use (Table 5).

7.3.3.2. Increase in Number of Dwellings

The residential pattern of the study area is characterized by scattered single family dwellings with several light density residential areas. Three-fourths of the dwelling units in the study area were constructed before 1964. Since 1963, 84 dwellings have been built in the area, with two-thirds of them constructed since 1969. Most of the construction has occurred in Segment II, including a residential subdivision (RL) of 22 homes southwest of the intersection of Plymouth-Ann Arbor Road with the existing M-14 freeway.

Within the Ann Arbor area, the housing market is said to be "very tight"; the growth of residential areas, especially extending north of the city toward the test site, might be taken as an indication that it is an expanding market as well. Though the fringe of these areas has not yet crossed north of the M-14 freeway, one might expect this to happen in the near future.

The increase in residential land use detected in the test area in the last nine years appears to be related in some degree to the impact of the M-14 freeway. This is particularly true in Segment II, where the Plymouth-Ann Arbor Road intersection is located. Dwellings in this area are nearer to Ann Arbor, in terms of travel time, than dwellings which are geographically closer. The only subdivision development constructed in the study area in the last nine years is located adjacent to Plymouth-Ann Arbor Road. The importance of accessibility in residential location seems again borne out in this case.

7.3.3.3. Increase in Commercial Activity

Only two commercial activities have been detected in the study area; a gas station and a trailer sales store. Both of these activities were in existence prior to the construction of the

M-14 freeway in 1964. One possible reason for limited commercial activity in the study area is the anticipated loss of access where Plymouth-Ann Arbor Road meets the M-14 freeway. Since the new interchange will be located west of this juncture, it may not yet be feasible for an entrepreneur to build. In addition, the population of the area has not reached accepted customer thresholds necessary for small stores to operate economically. There is little basis on which to project commercial growth along the M-14 freeway other than for auto-oriented services at major intersections. These are likely to occur once the M-14 freeway is completed to Plymouth.

7.3.3.4. Increased Industrial Development

There is only one type of industry located within the study area, the extraction of sand and gravel. Two sites in the study area, opened since the construction of the M-14 freeway began in 1964, provide basic materials for construction and road fill. Neither of these sites provides any major processing of the material but are mostly concerned with removal and some screening. One possible reason for this reduced service is the existence of larger scale extractive operations just north of the study site. These operations appear somewhat related to the construction of the M-14 freeway, but the limitations placed on their size by nearby activities make it appear unlikely that this area will be a major supplier after the completion of the freeway.

7.3.4. ASSESSMENT OF CHANGES

The assessment of changes in land use resulting from the impact of highway construction must be made in the light of several realities. First, the lag between general knowledge of impending highway construction and its actual completion may stretch beyond fifteen years. Thus, speculation, changes in tax structure, changes in the natural environment, and many other elements may contribute to the change of land from one use to another. The actual loss of land to highway right-of-way will be small in comparison to the changes in use created by the knowledge that an expanded highway is planned.

Second, the changes in land use must be considered in the context of the regional forces affecting both land ownership and use. These forces will affect the use and productivity of land, especially in the M-14 Test Site, located at the moving fringe of metropolitan Detroit.

Recognizing these external influences, the actual changes in land use in Segment I noted in the previous discussion appear to be primarily the result of factors other than the impact of the highway construction. This conclusion applies only to the particular circumstances of the development of Segment I during the period studied. It does not offer a model for predicting the impact of highway construction on land use in Segments II and III, since the construction of M-14 in these segments will complete a vital link in the overall transportation network of Southeast Michigan.

7.3.5. PREDICTION OF IMPACTS

The most evident impact of construction in Segments II and III will be that land devoted to actual right-of-way for the highway. The analysis of 1972 land use for Segment II indicates that the proposed right-of-way will pass through areas of agriculture, forest, and idle land. No dwellings or structures will be removed. At least three fields of row crops will be dissected by the highway, requiring new access routes for cultivation. In Segment III, the effects will be more extensive. The proposed right-of-way will require the removal of at least six dwelling units. The route will again dissect a number of agricultural areas, and at one point require special arrangements to continue the supply of surface water to a commercial sod farm.

It can be expected that with the addition of an access point to the M-14 freeway at Gottfredson Road, agricultural and idle land will be developed for residential uses. The strip residential pattern now found in the rural areas of Segment III will probably be accompanied by light density residential developments.

An assessment was also made of the influence of traffic noise generated by the highway. With the methods described in Ref. [30], an analysis was made to determine the width of strips on either side of the proposed M-14 extension which would fall into various categories of site exposure. For the afternoon peak-hour traffic estimated for 1990, it was found that the noise would fall in the "Normally Unacceptable" category from the edge of the right-of-way to a distance of 215 m (705 ft) from the edge. This area of limitation on both sides of the right-of-way amounts to 43 hectares/km of highway (170 acres/mile of highway). For areas which are rated Normally Unacceptable, the noise exposure is sufficiently severe that "unusual and costly building constructions are necessary to ensure some tranquility indoors, and barriers must be erected between the site and the roadway to make the outdoor environment tolerable" [30].

ANALYSIS OF REMOTE SENSING TECHNIQUES

Various forms of remote sensing imagery for providing information useful in highway impact assessment are discussed in this section. The primary emphasis of the discussion is on the use of multispectral scanner imagery, but the role of aerial photography in the identification of soil drainage classes, and as base maps of soil surveys is also involved. Since the principles of operation and application of multispectral scanners are not widely understood, they are described in Section 8.1.

8.1. MULTISPECTRAL SCANNER APPLICATION

The airborne multispectral scanner and its associated data processing equipment were developed as a means of extending remote sensor information that can be gathered and analyzed concerning features of the earth's surface while reducing the time and effort devoted to human interpretation of large quantities of imagery.

The use of automated techniques with multispectral data to provide information for highway impact assessment is described in the following discussion. Results shown are illustrative of the current state of the art in the use of scanner data. Research in these methods under other programs is aimed at improving resource mapping reliability and reducing the time and cost of obtaining the final product.

Specific objectives of this work were:

- (1) to classify and map major soil, water, and vegetation categories using automated (computer) techniques
- (2) to present the results in a readily reproducible (black-and-white) and interpretable format
- (3) to provide preliminary evaluation of the results and compare them with those obtained by other means

The products of the multispectral system are presented in three forms, the enhanced image, the single class recognition image, and the multiple-class image-map. In several of the figures, aerial photographs and soil drainage and vegetation maps are provided for comparison purposes.

Computer processing of multispectral data is designed to identify and map various types of features in a scene by using information from a number of spectral bands (or wavelength ranges). The multispectral scanner (MSS) extends the ability to record an image in the visible range, for which the human eye is sensitive, to invisible ultraviolet and infrared regions of the

radiation spectrum. The MSS divides this spectral region, from 0.32- to 13.5- μm wavelength, into a number of discrete bands. Thus, significant spectral detail is obtained by the MSS in the visible region which may not be discernible to the eye. In addition, reflectance and emittance (temperature) information is recorded from the infrared portion of the spectrum.

The value of additional spectral information is analogous to the increased ability to identify correctly and map crops or soils by means of color photography rather than black-and-white [31]. Black-and-white photography records information in a single spectral band, color film uses three bands, and the MSS records up to 12 bands of spectral information [32].

The difference between automated processing of MSS data and conventional human photo-interpretation should be noted. The photointerpreter identifies surfaces or objects in an image on the basis of his knowledge of scene characteristics, including the color, shape, texture, size, pattern, and relationship of ground features. Processing of MSS data substitutes for this variety of identification parameters recognition of features by detailed statistical spectral analysis. In other words, only the single parameter of scene radiation is used for identifying features by the computer.

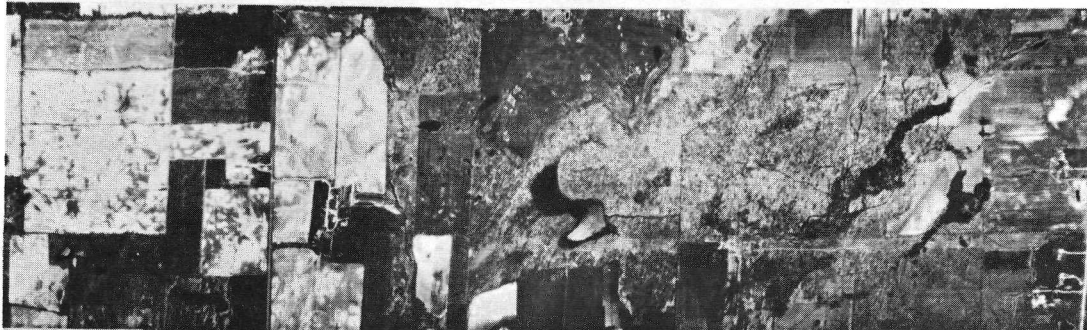
Previous studies indicate a wide variety of surfaces which may be separately mapped by computer [33-44]. Because the method is a statistical one, based on the uniqueness of terrain spectral characteristics, some classification error occurs because of natural variations of terrain surfaces. As with photointerpretation, the operational use of this method requires that identification and mapping errors remain within acceptable limits.

Scene information obtained by a MSS can be played back from recorded magnetic tape in a number of forms. The simplest is a set of photo-like images, each image showing the scene in one spectral band (see examples in Fig. 20). These may be manually analyzed using photo-interpretation techniques. Alternatively, several computer implemented processing techniques can be applied to the data. The computer acts as a filter to reduce the amount of information presented to the analyst or user. One form of processing is that of level slicing. A single channel of data is divided into two or more increments on the basis of signal levels in that band representing the lightness or darkness of the scene surface or feature. The technique is somewhat similar to film densitometry except that the scene information is taken directly from magnetic tape rather than a film base. Surface water mapping, for example, was accomplished by processing a single channel of magnetic tape, containing the 1.5 to 1.8 μm near infrared band. Because of its low reflectance of solar radiation in this band, surface water is distinguished from other surfaces by printing out only areas in which the tape signal falls below a certain level.

A second technique, ratio processing, determines the ratio of radiances in two spectral bands. Thus, only relative radiance differences between the two bands are displayed. This



9.3-11.7 μm (thermal)



2.0-2.6 μm (reflective IR)



0.67-0.94 μm (reflective IR)



0.48-0.52 μm (blue-green)

FIGURE 20. SCANNER IMAGES IN FOUR MULTISPECTRAL BANDS

technique produces an enhanced image in which vegetation or other surfaces may appear in greater contrast than on the original two images. Figure 22 shows an example of a ratioed image. Subsequently, level slicing to divide the ratioed data into discrete ranges may be done. Both level slicing and ratio processing are relatively simple and economical techniques. These are essentially unsupervised classification techniques which require no a priori training sample information.

A third approach uses several channels of data simultaneously and spectral information from selected sample areas. With this technique, the user selects training sets, sample areas on the ground that are typical of the different types of surfaces he wishes the computer to map. The computer is programmed to analyze and remember the spectral characteristics for the training sets. Then the MSS data for the entire scene is run through the computer. The computer rapidly compares the spectral characteristics from each resolution element in up to 12 bands with those of the training sets. For resolution elements similar to a given training set, the computer prints out a single recognition image. The process is repeated for each type of surface represented by a sample training set or combination of training sets. Each recognition image may be examined individually, or combinations of several images may be prepared as a series of overlays. The combination of a series of overlays results in a composite image-map in which different colors or patterns represent different recognition classes.

8.2. FLEMING CREEK WATERSHED

The drainage basin is a basic unit of terrestrial hydrology, and environmental changes which occur in one portion of a drainage basin are likely to affect other areas of the basin. In particular, environmental changes which occur in upper areas of a basin affect the quality, quantity, and timing of downstream water flow. Runoff and streamflow, in turn, affect and are affected by vegetation, soils, and land use. The basic hydrologic unit for this study is the Fleming Creek watershed. Existing and proposed portions of the M-14 freeway go through the central and upper portions of this largely rural watershed. The area of the watershed is about 60 sq km.

Infrared photography is generally regarded as providing the most useful and reliable contrasts for vegetation discrimination and identification by the photointerpreter. Figure 21 shows an annotated black-and-white infrared photomosaic of a major portion of Fleming Creek watershed. This photography, collected on 5 May 1972, shows newly emerging crop vegetation as light in tone and the deciduous forest and brushland areas as medium in tone. Note that both clouds (light) and cloud shadows (dark) obscured some portions of the watershed at the time of aircraft data collection. Unfortunately, bare soil areas also appear light to medium dark in tone, similar to the herbaceous and annual vegetation, making the discrimination of bare soil from vegetation somewhat unreliable. The annotation on this image shows the segments and detailed areas of the Fleming Creek watershed discussed in other portions of this report.

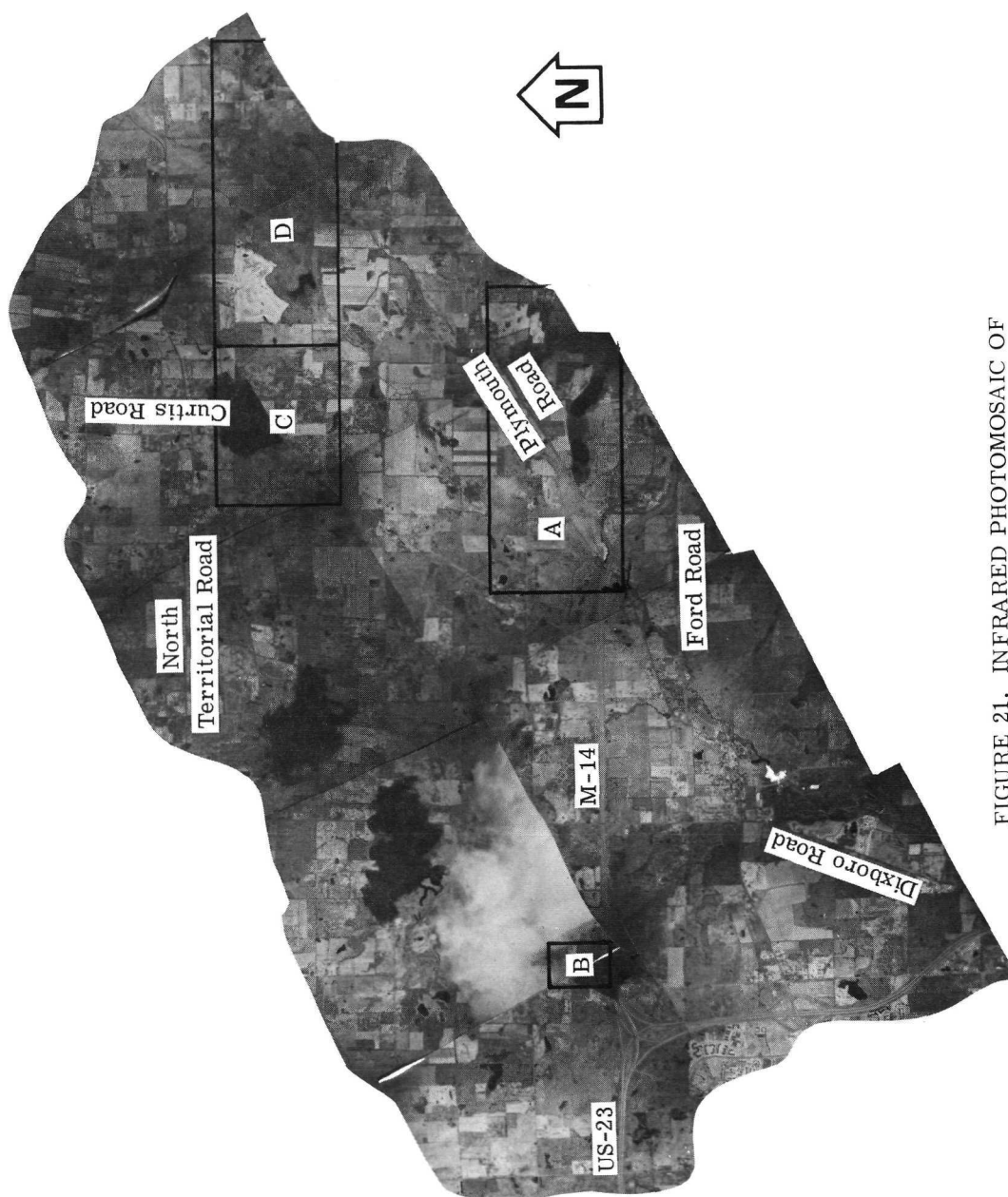


FIGURE 21. INFRARED PHOTOMOSAIC OF THE FLEMING CREEK WATERSHED. Detailed investigation areas are delineated.

Figure 22 shows an enhanced image-mosaic of Fleming Creek watershed, produced by ratio processing of two flightlines of scanner data. The two spectral bands used to produce this image were the 0.62-0.68 μm (red) and the 0.68-0.95 μm (near infrared) bands. In this image, green vegetation areas are dark in tone, forests and woodlots are medium, and bare areas are relatively light (as are roads and buildings). Also note that while the areas obscured by clouds remain (now dark), the cloud shadows have been eliminated. The use of this image enhancement technique also virtually eliminates image tone differences due to directional reflectance variations of scene features and edge vignetting caused by the optical system. Thus, contrasts of this enhanced image help in distinguishing between bare soil and kinds of vegetation and remain consistent from one flightline to the next. This is one example of a number of enhanced scanner images which may be constructed. Others can be used to emphasize patterns of drainage, bare soils, or cultural features [45]. The scanner image mosaic, however, lacks much of the fine detail and geometrical fidelity of the photo-mosaic.

In Figs. 23 through 27, general classes of vegetation, bare areas, and surface water areas are discriminated. The recognition images indicate some of the actual complexity of the distribution of terrain features for the Fleming Creek watershed.

Figure 23 shows locations of fields which contain newly emergent small grains (oats and wheat) and other cultivated grasses (dark areas on image). Included are green fields of a sod farm, a cemetery, and the verdant growth in the roughs of a golf course. The extensive detail in this image includes the non-uniform characteristics of crop growth within fields.

Figure 24 shows the most general classification obtained for the Fleming Creek watershed. The image generally represents the distribution of areas of natural (uncultivated) vegetation. These include perennial grass areas, brush and idle lands, and deciduous forest. In general, areas having the greatest density are wooded, although some fields containing grass are also quite dark.

Bare soil areas and most roads, including the existing M-14 freeway, are shown in Fig. 25. The roughly rectangular areas are plowed fields having little or no vegetation. Most of these fields were planted with corn later in the season. Patterns within fields are a result of poorly drained or vegetated spots not being recognized. Areas bare of vegetation appear to be correctly delimited on this image, including roof areas within the suburban residential area in the lower left of the image. Some false classification of surface water areas are also included on this image.

Because the computer sequentially analyzes each resolution element of an image (a square area 7 m on a side in this case), it can also tabulate the total area of each of the recognition classes. In Table 6 is given the percentage of the total area and the computed actual area of each of the examples of recognition images shown, exclusive of areas obscured by clouds.



FIGURE 22. ENHANCED IMAGE MOSAIC OF FLEMING CREEK WATERSHED. Green herbageous vegetation is dark; bare fields are light in tone.



FIGURE 23. RECOGNITION IMAGE OF NEWLY EMERGENT (SEEDLING) SMALL GRAINS AND OTHER CULTIVATED GRASSES FOR FLEMING CREEK WATERSHED. 5 May 1972.



FIGURE 24. RECOGNITION IMAGE OF AREAS
OF NATURAL VEGETATION, WOODLOTS AND
IDLE LAND FOR FLEMING CREEK WATERSHED.
5 May 1972.

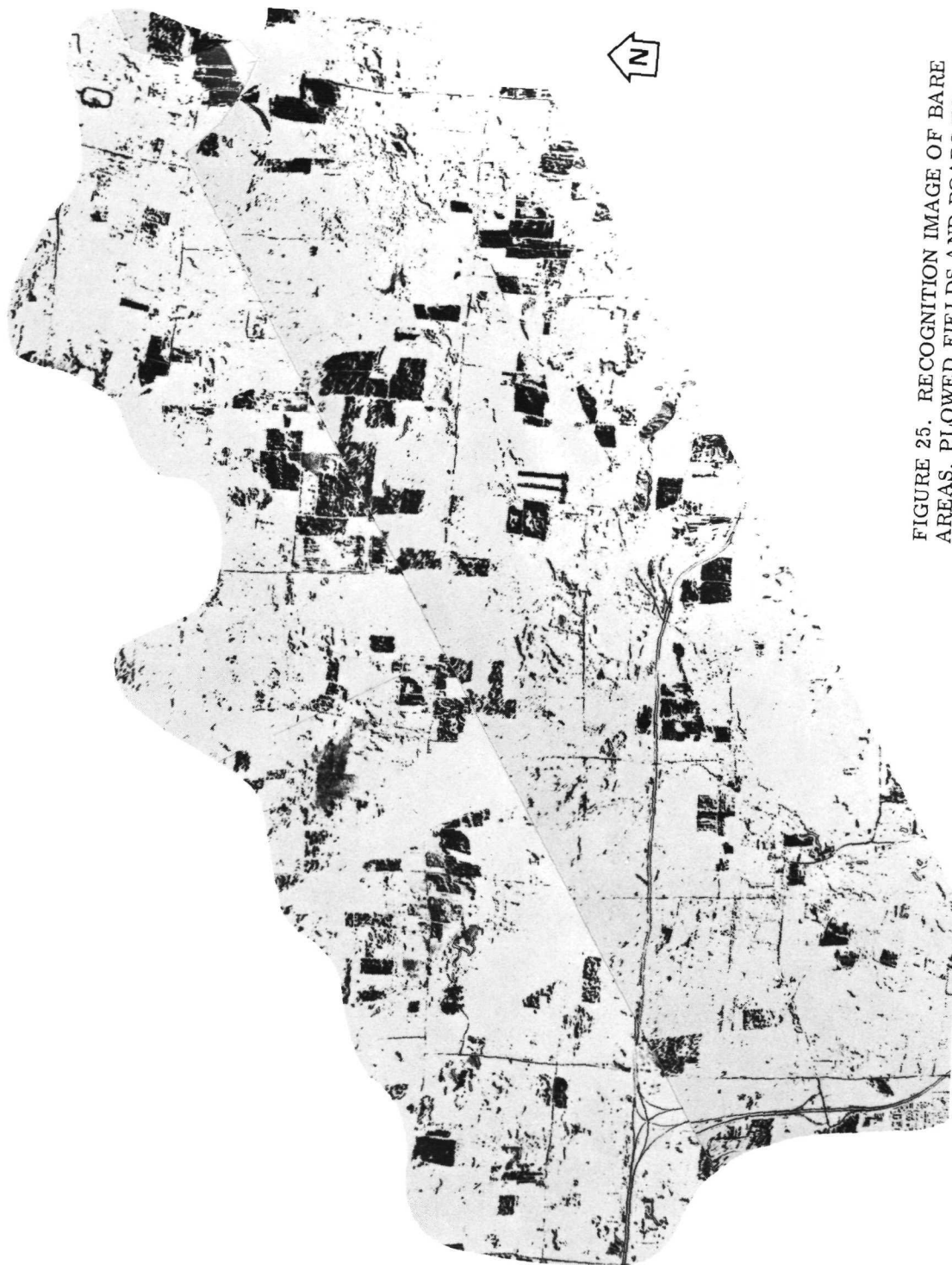
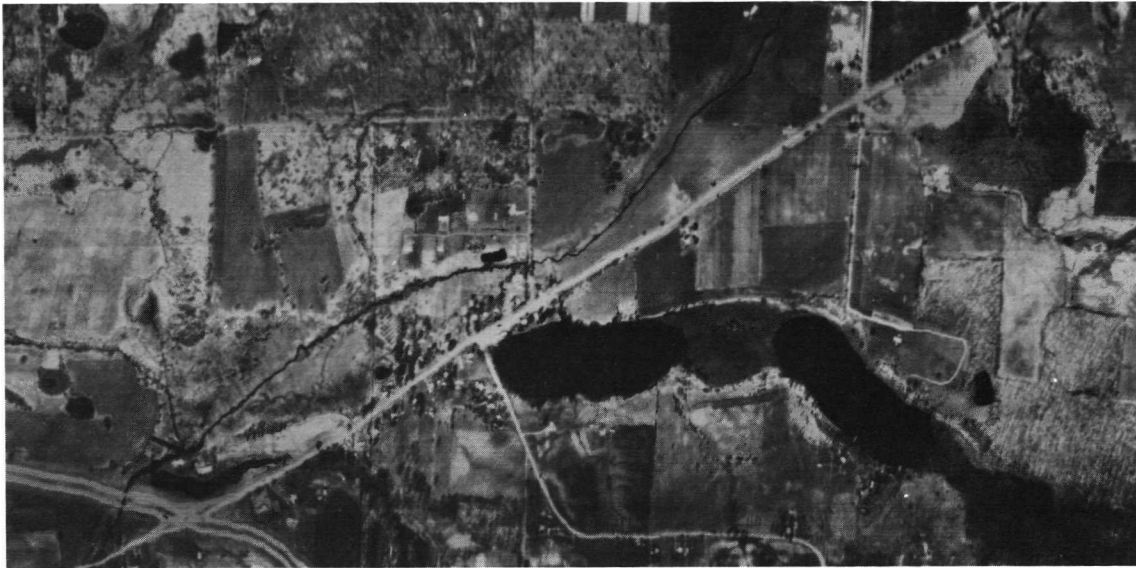


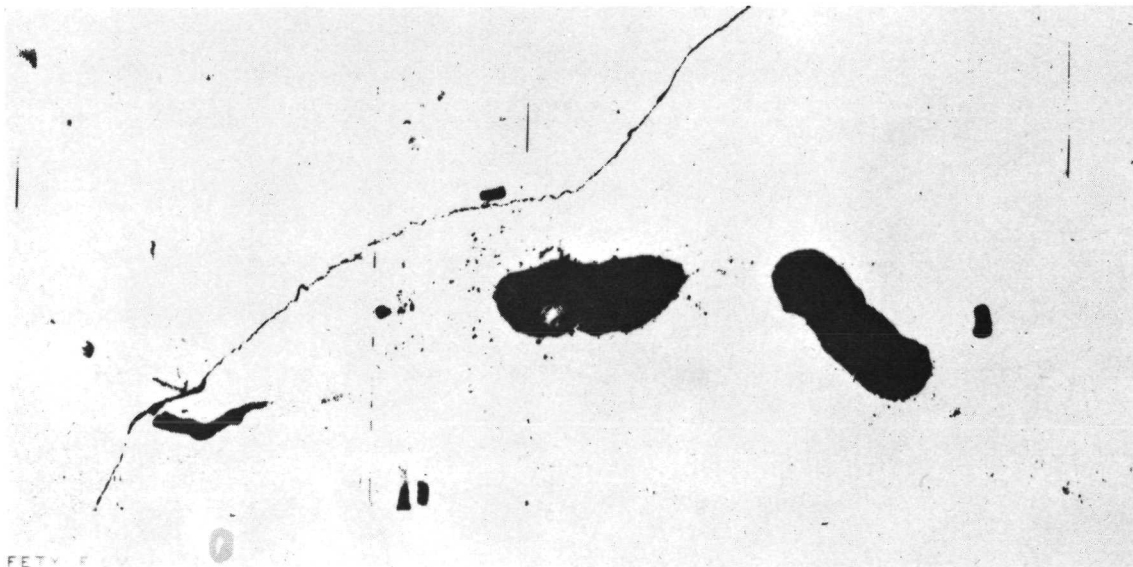
FIGURE 25. RECOGNITION IMAGE OF BARE AREAS, PLOWED FIELDS AND ROADS FOR FLEMING CREEK WATERSHED. 5 May 1972.



FIGURE 26. RECOGNITION IMAGE OF SUR-
FACE WATER AREAS FOR FLEMING CREEK
WATERSHED



(a) Thermal Image



(b) Recognition Image

FIGURE 27. COMPARISON OF A THERMAL IMAGE AND SURFACE WATER RECOGNITION FOR DETAILED AREA A OF FLEMING CREEK WATERSHED

TABLE 6. COMPUTER-DETERMINED AREAS
FOR FOUR RECOGNITION CLASSES

Recognition Class*	Area (%)	No. of Hectares	Figure No.
Seedling Small Grains	3.4	288	23
Natural Vegetation	24.8	2100	24
Bare Areas	10.6	967	25
Surface Water	0.7	59	26
Unrecognized	60.5	5055	—

*A number of other classes were recognized in this study, but these four are considered sufficient to illustrate the technique.

These percentages were obtained from an area including but somewhat larger than the Fleming Creek watershed, owing to the difficulty of defining the irregular outline of the watershed for the computer. The percentages of recognition classes are roughly applicable to the watershed because of the apparent similarity of land use in the adjacent included areas.

8.3. SURFACE WATER DISCRIMINATION

The nature and location of bodies of surface water are indicative of surface hydrologic conditions and are often representative of subsurface hydrology. As discussed in Section 4, highways have a potentially major impact on local hydrologic conditions. Figure 26 shows computer recognition of surface water for the Fleming Creek watershed. Dark areas on the image represent areas which were designated by the computer as surface water. Major pond areas are delineated, although Fleming Creek itself was not discriminated. Only surface-water areas equal to or larger than the resolution of the multispectral system were delineated—approximately 130 sq km in this case. In several instances portions of fields of dark saturated bare soil and cloud shadows were incorrectly recognized as surface water.

Image detail is determined by the aircraft altitude during data collection. Figure 26 was produced from data collected at 2100 m above the terrain; Fig. 27 uses data obtained at 600 m. Figure 27 shows a more detailed look at a portion of the watershed. Frain Lake, Murray Lake, and the surface of Fleming Creek are delineated. This stream is approximately 2 m wide at this point. This area of the watershed is indicated in Fig. 21.

8.4. NATURAL SOIL DRAINAGE

Three characteristics of soils are significant for highway impact studies—soil texture, soil slope, and natural soil drainage. Soil reports for surveyed areas include these characteristics and other related properties. Of these characteristics natural soil drainage is currently the most amenable to automatic classification—although techniques for obtaining information on soil texture are being developed. The observed spectral properties of soils of differing natural drainage are discussed in Appendix I.

Several limitations in the use of automatic mapping of soil characteristics should be mentioned. Direct observation of the soil surface by a remote sensor requires that coverage be obtained during a period when a substantial portion of the ground is clear of vegetation. Both live and dead vegetation will interfere with the spectral analysis and subsequent classification of the soil. Also, the MSS records only the surface of the soil; differing soils of similar surficial appearance will be classified as similar in computer analysis.

Four multispectral bands of the 12 which were originally recorded were selected for use in computer classification of natural soil drainage for both the May data and the June data

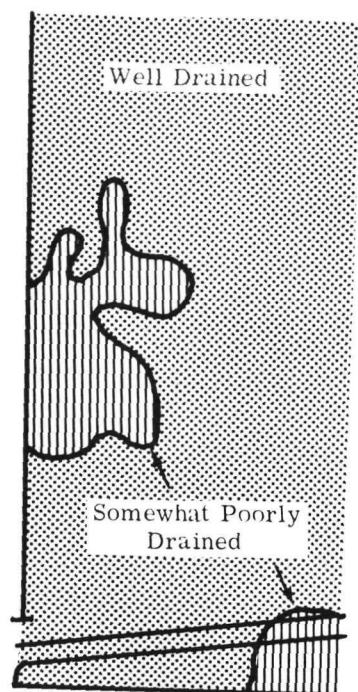
[May: 0.48-0.52 μm (blue-green), 0.67-0.94 μm (near IR), 2.0-2.6 μm (mid IR), 9.3-11.7 (thermal IR); June: 0.32-0.38 μm (UV), 0.48-0.52 (blue-green), 2.0-2.6 μm (near IR), and 9.3-11.7 μm (thermal IR)]. Six spectral recognition classes for each date were the result of this multichannel processing technique.

Figure 28 compares MSS recognition images for three different drainage classes with the soil drainage map of the same area (portion of Fig. 31). This drainage map (and succeeding ones) is based on soil survey maps developed in standard fashion by a soil scientist's observation of the landscape, combined with auger borings and aerial photo interpretation [46]. The computer-generated distribution of soils of the well-drained and somewhat poorly drained classes compares well generally with the soil drainage map. The poorly drained soils recognized by the computer comprise too small an area to be differentiated on the conventional map. Field examination determined that this area was indeed poorly drained.

Another area selected for study was adjacent to Curtis Road in the eastern portion of the watershed (Area C, Fig. 21). This area is also shown on the left side of the four video images shown in Fig. 20. These images represent the four channels which were used for automatic processing. There is a considerable contrast contained within the data—both within small portions of the imagery and between spectral bands for the same area.

Figure 29 shows a composite image-map in which different recognition classes are indicated by different tones—the lighter tones representing better drained soils. A 1:24,000 scale soil drainage map is provided for comparison. Within bare fields the general pattern of recognition corresponds to that shown on the drainage map, although greater detail is evident in the image-map. A much greater proportion of the area was recognized as well to moderately well drained soils than was evident on the drainage map. The correspondence of the two maps is fairly good for some fields, but for many others the dominant drainage class is shifted to one class better or poorer. In one case a field of alfalfa was incorrectly classified as a bare soil area well to moderately well drained. Black areas were not classified by the computer as belonging to one of the soil recognition classes.

In another study, a densitometry technique was used with aerial photography of this same area. A map showing an interpretation of the natural soil drainage (Fig. 30) was prepared by an individual having no previous experience with identifying soils in the field or from photos. A Macbeth-Ansco densitometer was used to determine variations in the density of a panchromatic photograph taken on May 21, 1969. Although some soil boundaries in bare areas were obvious, soil boundaries in vegetated areas were more difficult to determine. In some vegetated areas, particularly where the vegetation cover was not great, print densities frequently reflected soil differences. Each field, however, had to be evaluated separately because the



Well Drained
(Miami Series)

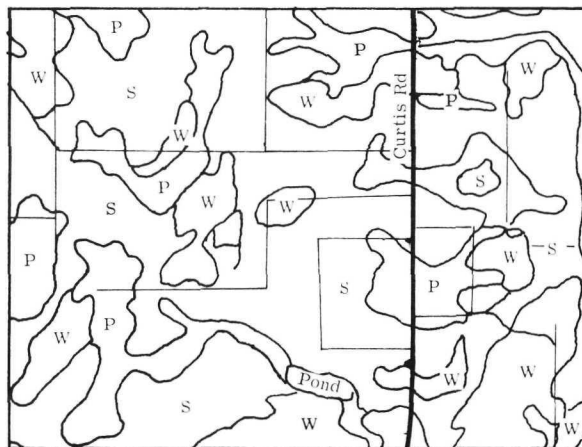


Somewhat-Poorly Drained
(Conover Series)



Poorly Drained
(Brookston Series)

FIGURE 28. COMPARISON OF A CONVENTIONAL SOIL DRAINAGE
MAP WITH SOIL RECOGNITION IMAGES FOR AREA B OF FLEMING
CREEK WATERSHED



W - Well Drained to
Moderately Well Drained
S - Somewhat Poorly Drained
P - Poorly Drained



Soils: { Well Drained
Moderately Well Drained
Somewhat Poorly Drained
Poorly Drained

FIGURE 29. COMPARISON OF A CONVENTIONAL SOIL DRAIN-
AGE MAP WITH A COMPOSITE SOILS RECOGNITION IMAGE
FOR AREA C OF FLEMING CREEK WATERSHED

**NATURAL DRAINAGE AS
DETERMINED FROM SOILS MAPS**



**NATURAL DRAINAGE AS INTERPRETED
FROM DENSITOMETRIC MEASUREMENTS
OF AN AERIAL PHOTOGRAPH**

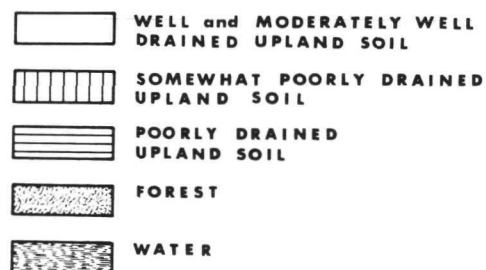
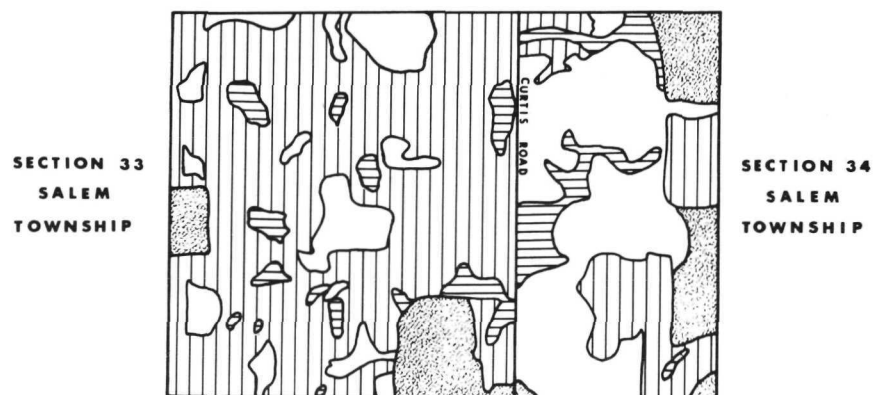


FIGURE 30. NATURAL DRAINAGE AS DETERMINED BY
DENSITOMETRIC SCANNING

differing crop and management practices resulted in different print densities. Fields were also delineated by natural soil drainage boundaries and cultural features such as roads. For example, the interpretation map shows soil boundaries on Curtis Road. Field observations indicate that soil delineations extend across Curtis Road in contrast to this interpretation.

The M-14 study results show that in some cases more than one computer recognition class was obtained for a single natural drainage class. Also, soils of two drainage classes were sometimes included in a single recognition image. In other words, the computer did not always recognize the same drainage classes that were obtained from soils maps of the same area. Indeed, some recognition patterns were noted which appeared to correspond to drainage classes other than that for which the computer was trained. Comparison of the imagery and the soil maps with field observations at points on transects of the areas show that both agree in 65% of the cases with the field observations of the natural soil drainage classes.

A major limitation of remote sensor use in this watershed was that only about 20% of the land was bare. In the M-14 freeway corridors, only about 10% of the land was in bare fields. The detailed mapping of soil drainage obtainable from multispectral imagery may be of use for surveys of bare areas.

There are several possible reasons for discrepancies between computer recognition images and the maps obtained from soil survey data. One is that the statistical method of computer analysis results in classification errors because variations in the surface reflectance of a given soil class from field to field and from one flight line to another. The computer decision criteria are based on the representativeness of selected sample areas. These sample areas or the training criteria may not be truly representative of their drainage classes because of changing scene illumination during scanning, differences in local topographic aspect, or differences in the terrain surface resulting from cultivation or vegetation. The use of training sets to program the computer to recognize similar scene elements was generally successful in classifying the natural soil drainage within adjacent bare fields. However, extension of this capability to other areas on the same flightline or to other flightlines was limited.

A second possible reason for lack of image and map agreement is that remote sensors record the soil surface in much greater detail than is usually obtained from soil surveys. Survey practice commonly allows a mapped area to include 45 to 55% soil series other than those named on the map. Areas 1 or 2 hectares in extent are commonly ignored in the soil mapping or shown by special symbols. The computer, in this study, mapped rectangular areas as small as 3 m on a side.

In spite of the general correlation of soil drainage with surface reflectance (Appendix I), it is not currently possible to define for a computer the spectral characteristics of soils which

consistently correspond to natural drainage classes. At best, we can use the computer to map detailed soil patterns within bare areas. Subsequent image interpretation or field checking can then be used to identify and confirm the recognition results.

An additional study was made, in an area shown in Fig. 6, to determine the capability of the computer to differentiate between soil textures. This attempt to separate textures was not successful. Similar difficulty in attempts to differentiate soil textures has been reported in Indiana [47]. Although differentiation of various soil textures is currently not successfully performed by computer processing of MSS data, techniques currently being explored may prove useful for this purpose.

8.5. VEGETATION CLASSIFICATION

The use of ratio processing techniques for vegetation discrimination in the Fleming Creek watershed was discussed in Section 8.2. Presented in this section are the results of an effort to produce generalized vegetation maps from computer processing techniques using multispectral data.

Computer classification of vegetation differs somewhat from classification systems used with manual photointerpretation techniques. In photointerpretation classifications, vegetation is identified and mapped on the basis of the interpreter's knowledge of vegetation, skill in delineating these, and patience in examining all areas of interest. The resulting classification may be based on the interpreter's knowledge of vegetation stature (forest/brushland), morphological structure (woody/herbaceous), or life cycle (annual/perennial) or on the basis of all of these. Computer-implemented classification discriminates different types of vegetation on the basis of a single physical attribute, the spectral characteristics of the vegetation. The multispectral data is automatically examined to determine which areas (resolution cells) belong to a known spectral vegetation class. All areas subsequently printed out by the computer were judged to be sufficiently similar to the known vegetation signature to be a member of that class.

Unique spectral signatures for several vegetation classes are shown in Fig. 31. This figure shows the mean values for the spectral characteristics of the vegetation classes in each of twelve spectral bands.

Figure 32 shows vegetation classification for the Frain Lake area of the Fleming Creek watershed (same area as in Fig. 27). Three categories of vegetation having significance for highway impact are identified—forest, marsh and swamp forest, and cropped areas. The cropped areas contain both newly emerging green seedlings and stubble remaining from the previous year's crop. Bare field areas are not recognized and printed out in any of the three maps, but would be expected to contain certain crops later in the season (mostly corn).

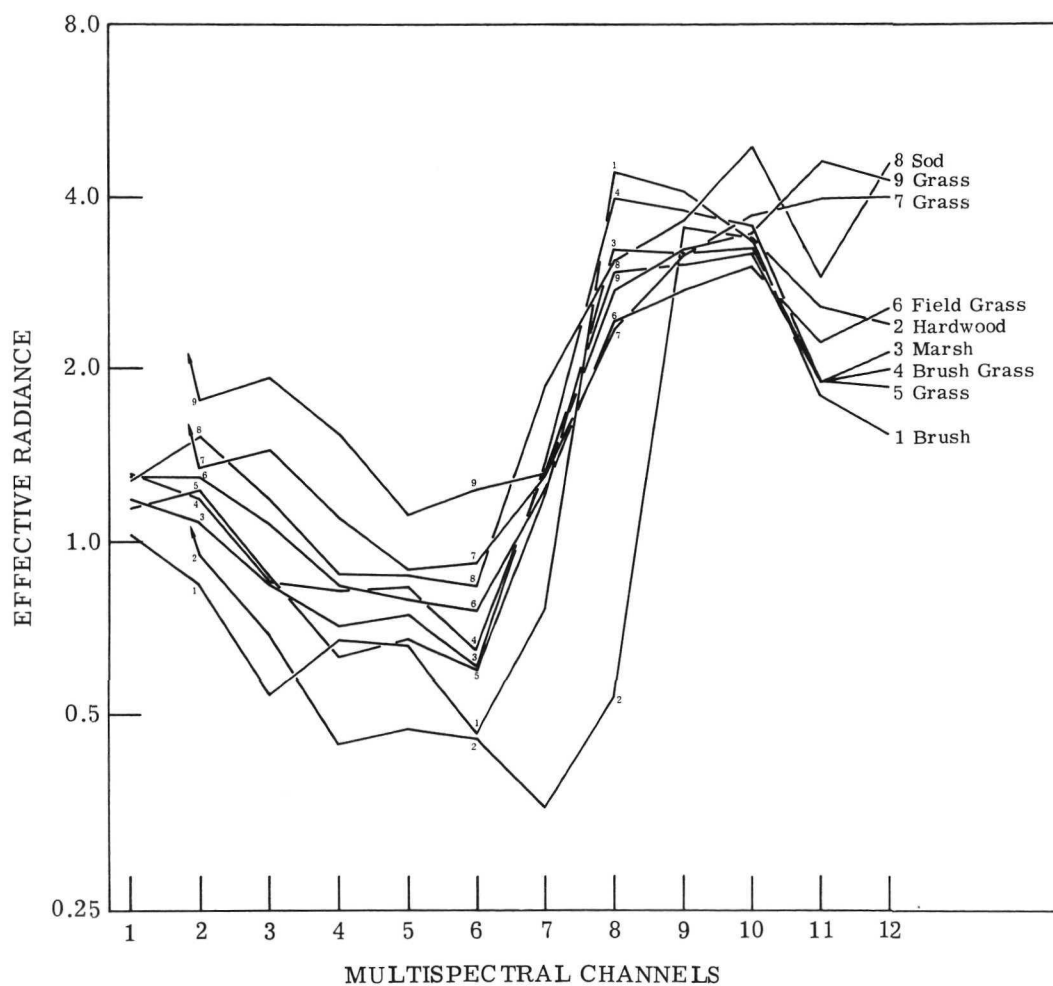


FIGURE 31. SPECTRAL SIGNATURES FOR VEGETATION CLASSES. 5 June 1972.



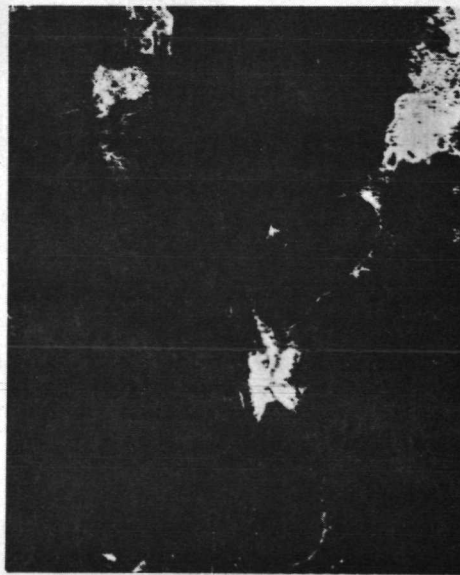
Deciduous Forest



Green Crops and Weeds



Thermal Video 9.3 - 11.7 μm



Lowland and Marsh

FIGURE 32. DETAILED VEGETATION RECOGNITION FOR AREA A OF FLEMING CREEK WATERSHED. 5 May 1972.

Figure 32 may be compared with the vegetative maps of Section 7. Corresponding individual fields or land parcels in each figure are not difficult to recognize. The comparison of categories is considerably more difficult, because they do not directly correspond to each other.

Figures 33a and 33b show composite recognition maps for an ecologically sensitive portion of Segment III. It is this area that the M-14 highway is scheduled to transect—probably with adverse effects on the environment. The central portion of this area is a lowland hardwood forest (deciduous forest). The presence of the forest is the result of the high water table associated with poor drainage conditions along this portion of Fleming Creek. Any changes in the drainage resulting from construction of the M-14 highway will adversely effect this hardwood swamp/forest. Vegetation surrounding the swamp/forest is a result of intermitted cultivation. Green crops and fallow fields are recognized, although the nonuniform densities and varieties result in only patchy recognition in some areas. In particular, recognition of vegetation is less complete using data obtained during June.

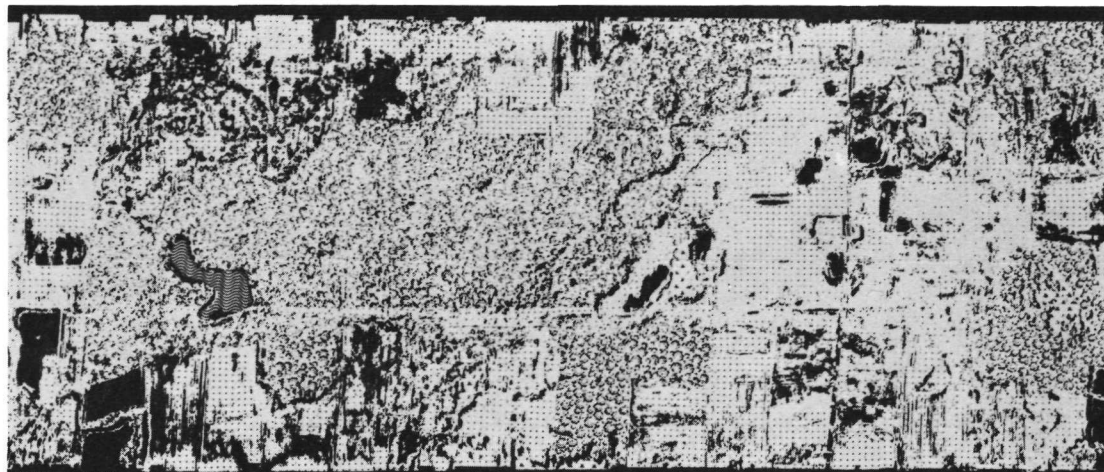
Most severely affected will be the swamp willow vegetation community which is found adjacent to the banks of the stream and around the edge of a pond within the swamp forest. Figure 34 shows this small portion of the swamp forest area.

This recognition map compares fairly well with the vegetation category map shown in Fig. 16, if the differences in categories are allowed for. In the recognition image the categories of fallow fields and scrub, green crop and lawn, and bare soil (consisting of much of the black areas) generally corresponds to the categories of herbaceous perennials and bare soil or annuals of Fig. 16. The category of deciduous forest in the recognition image corresponds with the categories of forest, and brushland or mixed. The comparison is somewhat difficult to make because the fine detail shown in the recognition image must be compared with the summarized form of vegetation mapping used in Fig. 16.

The vegetation mapping results presented in this section illustrate methods which can be considered for adoption either as individual techniques or in combination with the vegetation category mapping procedures suggested in Section 7.2.

Past development efforts in computer analysis of multispectral scanner data have been concentrated on discrimination of individual crop types or tree species. This capability is useful for identifying and mapping individual species or communities which are of special concern in impact assessment.

As indicated in this section, multispectral analysis methods can also be used to divide vegetation cover into a number of general classes. This work was an initial step toward presenting information in the form of 3 or 4 gross categories which are significant for impact assessment.



Vegetation and Water:



Deciduous Forest

Swamp Forest

Fallow Fields and Scrub



Green Crop and Lawn

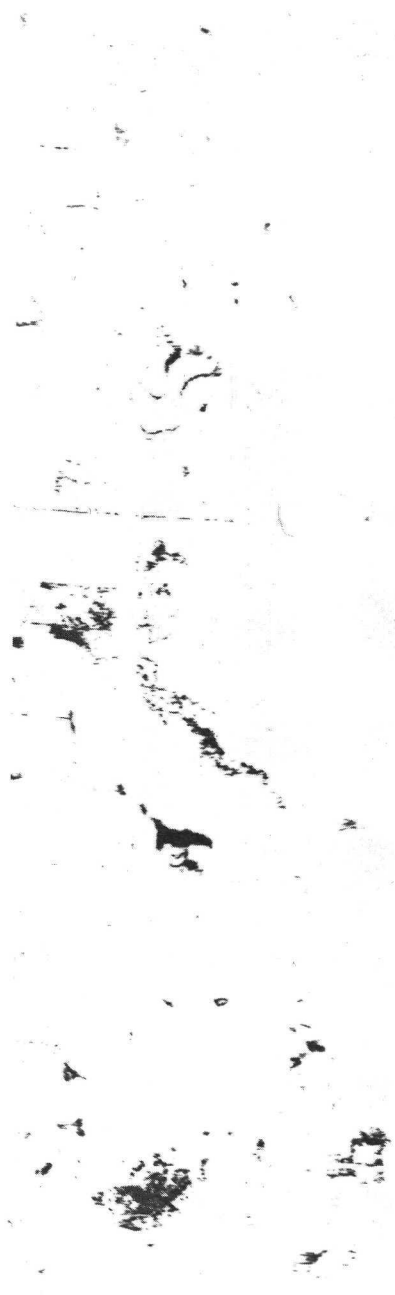
Standing Water (Ponds)

5 May 1972



5 June 1972

FIGURE 33. COMPOSITE VEGETATION AND SURFACE WATER RECOGNITION IMAGES FOR TWO SEASONS



(a) Video Image

(b) Vegetation Recognition Image

FIGURE 34. COMPARISON OF VIDEO IMAGE (0.41-0.48 μm) AND VEGETATION RECOGNITION IMAGE OF AREA D—EXTREMELY SENSITIVE TO HIGHWAY IMPACT

The separation as accomplished by spectral analysis corresponds in some respects to the four-category vegetation maps discussed in Section 7.2, but the correspondence is not complete. The inventory of vegetation categories derived from multispectral analysis also differs from that derived by photointerpretation with respect to information detail and operational methods. Consequently, the various methods of vegetation mapping may be considered either as alternate approaches or complementary approaches to providing data needed in impact assessment. Alternative methods may be useful under different circumstances, such as at different stages of the route selection process or in substantially different types of terrain.

Since the four vegetation categories have been selected with a view to their significance in assessing impact, it is desirable to investigate the possibility of improving the degree of correspondence of category mapping by multispectral means with that obtained from human photointerpretation. A modification of category definitions, or further development and adaptation of multispectral methods could substantially increase the convenience and usefulness of the vegetation data for impact assessment purposes.

9

AGENCY INVOLVEMENT AND INCORPORATION OF RESULTS

The Environmental Liaison Unit of the Michigan Department of State Highways is charged with carrying out evaluations of the impact of highway projects throughout the State of Michigan. The Unit provided the project staff with an opportunity to apply operational as well as experimental techniques in remote sensing. Their assessment process, though admittedly preliminary in parts, does provide for the consideration of a number of factors heretofore not formally studied.

Following the initial series of meetings with the staff of the Environmental Liaison Unit as to the forms of information needed to improve the impact assessment process, work was begun in earnest. The goal here was to involve the agency's staff in as many aspects of the work as possible. That goal was partially achieved.

The agency's assistance was vital in the selection of a test site, and in defining the objectives of the study. No fewer than four meetings were held with representatives of the MDSH to determine a project vehicle meeting the needs of all concerned. The M-14 Test Site was selected with the concurrence of the Liaison Unit.

The data collection efforts were carried out with the assistance of the staff of the Liaison Unit as well as research divisions of the MDSH. All efforts necessary to ease the project staff's access to the test site were taken by the agency.

During the analysis stage, a number of meetings were held with individual members of the Liaison Unit. In addition, a full briefing of the project's progress and intended directions of research was made to staff of the MDSH at a point in the research which would have allowed redirection if it was seen necessary. Problems were aired, and a general consensus reached that the project's continued efforts would result in a product useful to the MDSH.

Aside from individual contacts with members of the Liaison Unit to discuss problems with the research, no formal re-involvement of the Unit in the project's research was made until first drafts of the project's report were completed. At that time, drafts of several sections of the report were submitted to the Liaison Unit for review and comment.

It is currently planned to use this completed report as the basis for a series of meetings in which the implementation of some of the results or techniques of the project will be discussed. On the basis of evaluations already received from members of the Liaison Unit, however, it appears that a number of elements of the research will be implemented.

(1) The expansion of information available through use of the RB-57 imagery will be sought wherever possible. Attempts will be made in the near future to incorporate the imagery directly into the route planning process as well as that of impact evaluation. The major stumbling block to full use of the imagery is incomplete coverage of portions of the state.

(2) The vegetation classification schemes described in this report have been partially implemented for portions of the impact evaluation and route location processes. The sensitivity of vegetative communities to intrusions documented in this and other studies has made necessary the consideration of more specific information about the landscape cover. For this reason, the species identification will be implemented in some instances.

(3) In the M-14 Test Site itself, information gathered in the course of the project on the natural drainage of the area's soils will be used in redesigning the highway's drainage system in an attempt to alleviate ground and surface water problems which might have arisen had the highway been constructed as planned.

It is expected that several additional elements of the research may be incorporated into the procedures of the Michigan Department of State Highways following the series of evaluation meetings to be held at the completion of the study.

Although substantial involvement of the MDSH was achieved during this work, experience indicates that increased involvement can be achieved through more frequent contact between the project staff and the Liaison Unit. Project work was carried out in quarters other than those of the Liaison Unit staff, which limited frequency of contact with the Liaison Unit staff. This problem may be alleviated to a large extent in future research with the MDSH and other agencies through a planned effort to conduct necessary analysis and interpretation in the agency's offices wherever possible. This should increase the mutual transfer of expertise and experience.

Appendix I SPECTRAL ANALYSIS OF SOILS

Spectral reflectance measurements of bare soils made in the field at the time of the multispectral flights show a general increase in reflectance with natural drainage at almost all wavelengths over the 0.40 to 1.3 μm range (Fig. 35). In particular, three well-drained soils had an average relative reflectance of about 20%, while two somewhat poorly drained soils reflected 11 to 15% of the incident radiation and a poorly drained soil reflected no greater than 8.5%. This ordering of reflectance with drainage classes is because the more poorly drained soils have higher relative surface moisture contents and organic matter accumulations.

The above reflectances were recorded in May, 1972 at a time of generally wet field conditions when all but the most rapidly draining soils were probably near field capacity. Multispectral data recorded at that time and processed for automatic discrimination of soil drainage classes show the same reflectance sequence—dark image tones are associated with poorly drained soil areas in the reflective bands. The exception to this rule is the appearance of poorly drained areas in the thermal infrared band. In the 9.3- to 11.7- μm thermal band, poorly drained soils appear distinctly light in tone, indicating somewhat warmer temperatures than the well drained areas. (See upper-left image in Fig. 20.) This phenomenon was confirmed by field recorded thermal radiometer readings (Table 7).

With the exception of the well-drained Morley series, surface temperature recorded for soils of the M-14 Test Site increase as the drainage class is poorer. The more poorly drained soils are darker in color and absorb more of the incident solar radiation than the light toned, well drained soils. Thus, in general the more poorly drained soils were warmer than the well-drained soils, with the somewhat poorly drained being intermediate in surface temperature. This trend in surface temperatures of soils of different drainage class is somewhat surprising but was recorded in the field at the times of both the May and June data collection flights. Normally one would expect cooler daytime temperatures associated with more moist soils due to the effects of evaporation and the high specific heat of water in the soil. The water contents increase with poorer soil drainage (Table 7) on a given date and thus tend to offset the darker colors of the more poorly drained soils. The warmest soil, Morley, in Table 7 had the lowest moisture content.

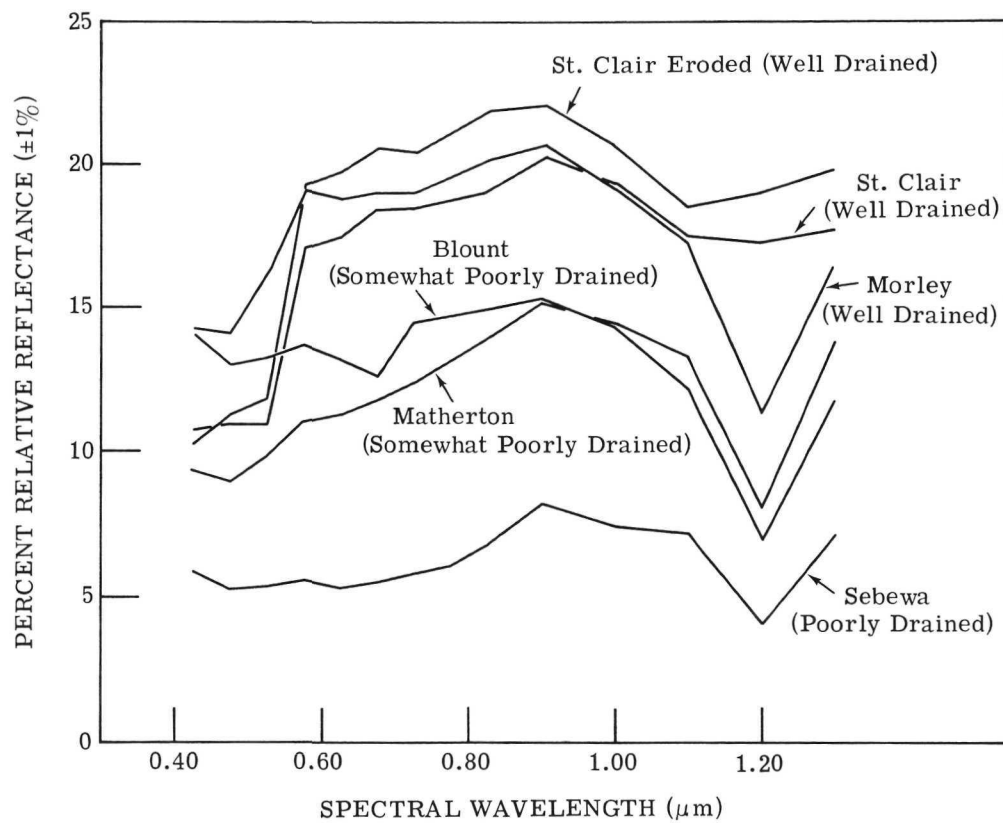


FIGURE 35. GENERAL REFLECTANCE MEASUREMENTS FOR SOILS OF THE FLEMING CREEK WATERSHED
5 MAY 1972

TABLE 7. SOIL DRAINAGE, CLASSES, MOISTURE, AND SURFACE TEMPERATURES FOR THE M-14 AREA FOR 5 MAY 1972

<u>Drainage Class</u>	<u>Time of Day</u>	<u>Surface Moisture (%)</u>	<u>Surface Temperature* (°F)</u>
Well drained:			
Morley Series	1241 hr	2.9	30
St. Clair (eroded)	1042 hr	4.7	21
St. Clair	1048 hr	7.2	19
Somewhat poorly drained:			
Matherton	1140 hr	9.0	23
Blount	1255 hr	9.8	24
Blount	1205 hr	14.1	21
Poorly drained:			
Sebewa	1135 hr	24.8	26

* Barnes PRT-5 Precision Radiometer filtered to 8.0 to 14.0 μm

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